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ABOUT THE COVER



Supermarkets represent an important public access to a wide variety of food that is vital to our health. The supermarket is also a location where food, the public, and pathogens can

meet. The study highlighted in this month's cover article, "The Spread of a Norovirus Surrogate via Reusable Grocery Bags in a Grocery Supermarket," developed and tested a hypothesized norovirus transmission pathway via reusable grocery bags (RGBs) within a conventional grocery supermarket. Study data show that the norovirus surrogate on the RGBs spread to all surfaces touched by the shopper, highlighting a public health risk and the need for better education, disinfection, and strategies to alleviate the risk.

See page 8.

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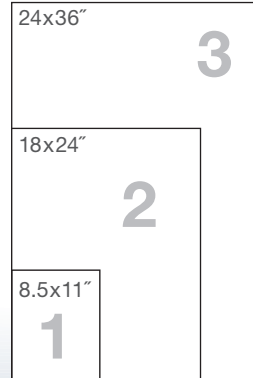


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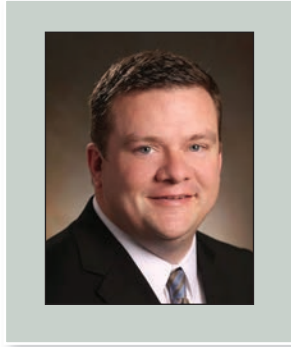
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► PRESIDENT'S MESSAGE



Adam London,
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The State of Our Association

It truly is amazing how fast a year passes. As I near the conclusion of my year in the presidential chair, I can't help but reflect upon the state of our association. The fact that you are reading this column suggests that you also care a great deal about environmental health. All of us who get involved with leadership at the National Environmental Health Association (NEHA) or within the state affiliates care deeply about this profession and we want to see our organizations rise to meet the challenges of a new day. We give our time as volunteers in pursuit of self-actualization and the satisfaction that comes with knowing that our blood, sweat, and tears actually contribute to a better world. With this in mind, I must report to you that your association is stronger than it has ever been, but not nearly as strong as it needs to be.

The organizational health of NEHA is demonstrated in many ways. The association has received clean financial audits for multiple years and has finished the past couple of years in the black after suffering significant losses during prior years. NEHA remains competitive for federally funded grant projects and cooperative agreements, which helps to ensure that we are able to be a difference-making organization. The most recent Annual Educational Conference (AEC) & Exhibitions in Grand Rapids and San Antonio were well attended with high member satisfaction scores. We have also secured outstanding locations for the upcoming AECs: Anaheim in 2018, Nashville in 2019, and New York City in 2020. Membership has grown to an all-time high of nearly 5,000 professionals. I hope you have also

*We are
making progress,
but we will
not achieve our
goals unless
everyone pulls
a little harder.*

noticed that the NEHA website and membership/learning platforms have been improved. Perhaps most important, we have beefed up our ability to influence environmental health policy. Staff located in Washington, DC, meet with elected officials and federal departments and advocate for better environmental health policy and for the environmental health workforce.

I have been honored to attend many meetings across the U.S. and to represent NEHA at the World Congress on Environmental Health earlier this year in New Zealand. It has been a pleasure to discuss the state of environmental health with my counterparts from dozens of places. I am always amazed at how similar environmental health professionals are, regardless of state or national origin. It is also clear to me that NEHA is generally held in high esteem by our state affiliates and international neighbors. And yet, we can do

better. We need to make sure the connective tissue and resource sharing between our like-minded organizations are strengthened. There are great opportunities for our organizations to speak up in unison for a healthier world. NEHA is on the cusp of approving several new and revised position papers. I encourage you to become familiar with, and use, the wealth of information that is contained in the position papers that can be found on NEHA's website (www.neha.org/publications/position-papers).

Despite these positive developments—and I could go on with a number of others—I believe that NEHA is not nearly strong enough as it needs to be. NEHA should be at the forefront in the minds of policy makers as they consider issues pertinent to human health and the environment. We are not there yet. While we have a record number of members, we should probably have twice as many, and those members need to be more engaged. The NEHA Endowment and Scholarship Funds can become dynamic forces for advancing environmental health projects and education if they are adequately funded and purposed. We are making progress, but we will not achieve our goals unless everyone pulls a little harder and recruits another colleague to the cause.

One of my earlier columns discussed the threats to funding of the Great Lakes Restoration Initiative (GLRI). I encouraged all of you to contact your representatives in Washington, DC, and stand up for this important issue. I am happy to report that the final spending bill included full funding of GLRI that is equivalent to prior years. Thank you for your actions—you contributed to a team victory.

Continue to be involved and do not underestimate the power that you have to change the course of history. Elected officials in Washington, DC, and in state capitols across the nation truly do listen to the concerns of their constituents. Place their office telephone numbers and e-mail addresses in your contact list. Phone calls and e-mails give them pause to consider the ramifications of their policy decisions.

Over the past couple of years NEHA has developed muscle in this arena. In addition to our Washington, DC, staff, we also held our Second Annual Lobby Day in Washington, DC, on May 1, 2018. During this day of polit-

ical advocacy, your NEHA board of directors and staff visited the offices of numerous elected officials to educate them about the importance of environmental health and the environmental health workforce. I have been encouraged by these conversations because I think many eyes are being opened to the fact that environmental health is a core component of national safety and security.

As this presidency comes to an end for me, I hope I can count on you to help NEHA reach its potential. This association and all its state affiliates need new leaders and volunteers. Please get involved for the sake of environmental health and for your own per-

sonal benefit. My time on the NEHA board of directors has required many hours of my volunteer time, but to be totally honest, it has been a fantastically fun ride. I hope to see you in Anaheim for the NEHA 2018 AEC & Exhibition and U.S. Department of Housing and Urban Development Healthy Homes Conference, June 25–28, and I hope to hear your aspirations for taking NEHA to new heights 🐼



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The Spread of a Norovirus Surrogate via Reusable Grocery Bags in a Grocery Supermarket

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Abstract The conventional supermarket represents an important public access to a wide variety of food that is vital for healthy families. The supermarket is also a location where food, the public, and pathogens can meet. The purpose of this study was to develop and test a hypothesized norovirus transmission pathway via reusable grocery bags (RGBs) within a conventional grocery supermarket. An RGB was inoculated with a surrogate virus to assess potential transport of pathogens within a grocery store. Volunteer shoppers were given an RGB sprayed with a surrogate (bacteriophage MS2) upon entry to a grocery store. A surrogate is defined in this study as an organism, particle, or substance that is used to study the fate and transport of a pathogen in a specific environment (Sinclair, Rose, Hashsham, Gerba, & Haas, 2012). The study personnel swabbed all surfaces touched by the volunteer shopper to recover the MS2 surrogate. The data show that MS2 spread to all surfaces touched by the shopper; the highest concentration occurred on the shopper's hands, the checkout stand, and the clerk's hands. The high concentration of MS2 on hands justify a recommendation for in-store hand hygiene as a primary preventive measure against transmission of infectious pathogens. The high concentrations on the checkout stand justify a secondary recommendation for surface disinfection and public education about washing RGBs.

Introduction

Norovirus is a pathogenic RNA virus that is the leading cause of acute gastroenteritis from contaminated food in the U.S. Outbreaks occur in restaurants, schools, hotels, home care facilities, cruise ships, and in the wilderness tourism industry. Norovirus outbreaks occur often during times of low humidity such as the winter season in temperate zones (Colas de la Noue et al., 2014; Jones, Gaither, Kramer, & Gerba, 2009; Seitz

et al., 2011). These viruses are a major concern for surfaces and fomites in the food production, service, and grocery retail industries (U.S. Department of Health and Human Services, 2018).

The objective of this study was to test a hypothesized norovirus transmission pathway via reusable grocery bags (RGBs) within a conventional grocery supermarket. A true norovirus transmission pathway is not possible to evaluate in a public setting, so a bacte-

riophage is used as a safe surrogate to assess the presence and concentration of the virus. A surrogate is defined here as an organism, particle, or substance that is used to study the fate and transport of a pathogen in a specific environment (Sinclair et al., 2012).

The MS2 bacteriophage is a suitable surrogate for norovirus because it is a single-stranded RNA virus with a similar structure and size to most noroviruses (Beamer et al., 2014). The MS2 bacteriophage surrogate can be used to model the survival, morphology, and transport characteristics of norovirus without the infection risk or the necessity of mammalian cell culture facilities (Dawson, Paish, Staffell, Seymour, & Appleton, 2005). This experiment models norovirus transmission with the surrogate MS2 introduced into a grocery store through an experimentally contaminated RGB.

This study builds on a previous work that investigated the potential for contamination in RGBs. The findings were that over 10% of all bags obtained from shoppers contained fecal indicator bacteria and that only 3% of all shoppers had reported ever washing their bags (Williams, Gerba, Maxwell, & Sinclair, 2011). Other studies have linked reusable bags with a norovirus outbreak in the U.S. Northwest (Repp & Keene, 2012) where an RGB was contaminated with aerosolized norovirus from an infected individual. This study investigates the potential for contaminated RGBs to distribute viruses within a public grocery store.

This study's hypothesis is that norovirus could be spread from a contaminated RGB to various public surfaces in the grocery store (Figure 1). The study purpose is to provide data that can help identify critical control

TABLE 1

The Log Concentration (LC), Category (Cat), Arithmetic Mean (μ), Geometric Mean (GM), Standard Deviation (SD), Number of Items Swabbed in the Grocery Stores (n), and Percent of Initial Inoculum (%I)

Item	Identification Letters	LC	Cat	μ	GM	SD	n	%I
Seeded reusable grocery bag	a	9	–	4.81×10^9	8.58×10^8	7.27×10^9	25	100
Hands								
Customer	b	7	C1	7.02×10^7	4.10×10^7	7.52×10^7	9	1.4600
Clerk	c	7	C2	9.30×10^7	9.30×10^7	9.30×10^7	4	1.9300
Cart								
Handle	d	5	C1	3.46×10^5	2.91×10^5	1.59×10^5	9	0.0072
Surface	e	5	C1	6.47×10^5	2.38×10^5	8.13×10^5	6	0.0130
Checkout								
Scale	f	5	C1	1.43×10^5	9.05×10^4	1.52×10^5	4	0.0030
Conveyor	g	4	C1	6.95×10^4	2.60×10^4	5.73×10^4	13	0.0014
Customer bumper	h	4	C1	6.07×10^4	1.23×10^4	7.97×10^4	6	0.0013
Clerk keyboard	i	4	C2	5.58×10^4	2.54×10^4	4.51×10^4	4	0.0012
Clerk table	j	4	C2	5.25×10^4	1.56×10^4	5.00×10^4	4	0.0011
Customer keyboard and table	k	5	C2	1.54×10^5	1.50×10^5	3.71×10^4	4	0.0032
Food								
Packaged	l	7	C2	2.90×10^7	3.75×10^5	5.91×10^7	11	0.6020
Unpackaged produce	m	6	C2	2.36×10^6	3.04×10^5	4.22×10^6	9	0.0490
Other								
Freezer handle	n	4	C2	2.45×10^4	1.94×10^4	1.17×10^4	6	0.0005
Other handle	o	4	C2	2.42×10^4	1.39×10^4	2.86×10^4	5	0.0005
Incentive card	p	5	C2	3.91×10^5	3.34×10^5	1.90×10^5	6	0.0081

Note. Darker shades of grey indicate a higher LC. The identification letters are used in reference to Figure 3.

points that could be the focus of improved norovirus management strategies in grocery stores.

Methods

Our hypothesized virus transmission pathway was developed in this field study using RGBs and a nonpathogenic microbial surrogate for norovirus. Volunteer shoppers were recruited in front of three grocery stores in California and instructed to complete their planned shopping trip using an RGB that the study team provided. The volunteer shopped using a store-provided grocery cart and was followed by a study team member who swabbed surfaces and items contacted by the volunteer shopper. The three site visit trips involved traveling to Atascadero, Ceres, and Madera in the Central Valley of California. The temperature and humidity were recorded

after the study using historical data from the closest National Climatic Data Center (NCDC)-affiliated weather stations to each grocery store site (NCDC, 2012).

A microbial surrogate was used to safely trace the norovirus transmission pathway in the presence of customers. The norovirus surrogate chosen was the MS2 single-stranded RNA bacteriophage obtained from American Type Culture Collection (ATCC #15597-B1). The MS2 surrogate was used because it can be produced in large numbers at low cost, can be easily detected, and is nonpathogenic (Sinclair et al., 2012). Also, MS2 is a safe, noninfectious laboratory strain not found in the natural environment or on fomites. For this reason, it was not necessary to decontaminate the bags and surfaces in the store before the study initiation.

Grocery stores were selected by contacting the California Grocers Association and the Environmental Safety Alliance. These two stakeholders were able to obtain access permissions and staff participation from three stores owned by PAQ, Inc. The three supermarkets were a Food4Less store in Atascadero, California, measuring 3,530 m²; a Food4Less store in Ceres, California, measuring 2,880 m²; and the Rancho San Miguel Market in Madera, California, measuring 5,561 m². The store area estimates were calculated using the polygon tool in Google Earth version 7.0.3.8542 (2013).

All three stores were of a similar layout with an identical checkout stand, allowing the customer to self-bag the groceries. The Rancho San Miguel Market is a larger store that closely resembles a Food4Less with added Latino food

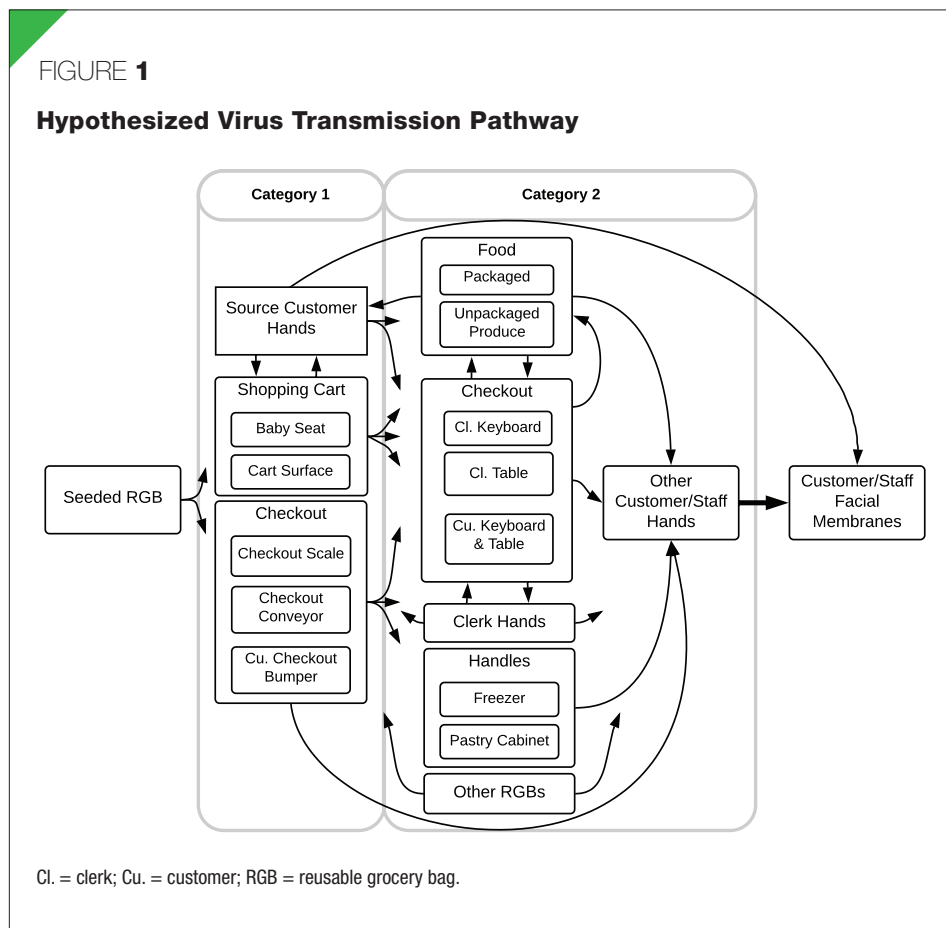
products. The majority Latino population in Madera (76.7%) and Ceres (56.0%) represent young Latino families, with the Atascadero market catering towards a White community (76.7%) (U.S. Census Bureau, 2010). The Atascadero location is a cooler coastal climate, while the other two stores are in the Central Valley of California.

The new RGBs used in the study were purchased for 98 cents each from the three stores on the date of the study. The bag material was unwoven polypropylene, a common cloth-like synthetic typically used for inexpensive RGBs. The same bag was available at each of the three stores and was sized at 36 x 34 x 18 cm and printed with a logo of Food4Less or Rancho San Miguel markets.

The bag and its handles were thoroughly sprayed with 5 mL of a 10^9 PFU/mL-concentration MS2 solution suspended in sterile Ringer's solution (Fisher Scientific). The spray bottle was a sterile 250 mL low-density polyethylene plunger-style bottle (Bel-Art, Fisher Scientific) that was prepped with a fresh MS2 surrogate stock for each of the study days. The MS2 bacteriophage #15597 was obtained from ATCC and propagated using the U.S. Environmental Protection Agency single-agar layer method (Ohio Environmental Protection Agency [EPA], 2005). A lawn of the host *E. coli* strain (ATCC #15597) allowed heavy plaque formation on trypticase soy agar (Difco) after 24 hr of incubation at 37 °C. The plaques were scraped from the surface of the agar and placed in 50 mL sterile centrifuge tubes along with 30 mL of sterile Ringer's solution buffer.

The MS2 surrogate concentration used in this study is a similar high concentration to norovirus that can be shed by an infected individual's vomit or feces (Sinclair, Jones, & Gerba, 2009). The RGBs were hung to dry in ambient outdoor air for 15 min, then folded and placed in individual, sealed Ziplock bags.

Volunteer shoppers were recruited from the entryway of the store after verbal consent, a brief introduction to the study purpose, and instructions. The shoppers agreed to shop for their normal items and to shop for the included list of items needed for the study. The volunteers were provided a list of items designed to control the travel and contact that the customers had throughout the store. Shoppers were motivated to follow through with the study by being informed



that they would receive an incentive at the end of the study.

The incentive was not disclosed upon recruitment; however, at the end of the study volunteers were given \$10–\$15 store credit on a gift card. The volunteers were then given the RGB to use when they checked out at the designated checkout stand after the completion of their shopping errand. Volunteers were given the RGB and intentionally not told what to do with the bag as they carried or carted it throughout the store. The study team ensured that the volunteer shoppers did not use a grocery cart used by a previous study participant. The Loma Linda University Institutional Review Board granted this study a waiver, because there were no health risks, no individual identifiers, and no health data were recorded.

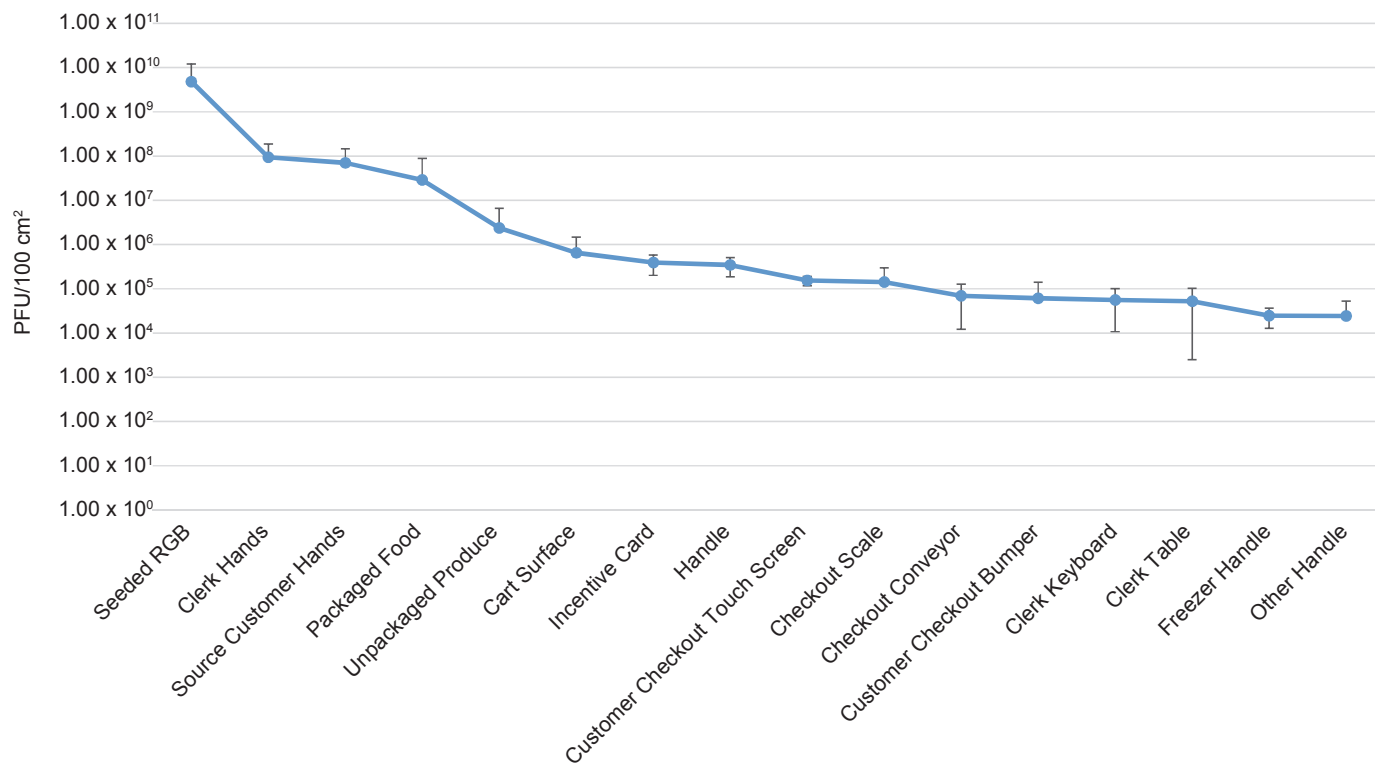
As the volunteer shopper moved throughout the store, a study team member swabbed a 100 mm² area of various surfaces that the shopper touched. For handles and other items that were not flat, the study team

member swabbed the area touched by the volunteer shopper and then labeled the tube with the surface area of that particular surface. The rayon-tipped swabs (Fisher Scientific) were stored in 5 mL of Ringer's solution (Fisher Scientific) as a transport buffer, placed in an ice cooler, and transported back to the Loma Linda Environmental Microbiology Research Laboratory.

The study team also swabbed all surfaces at the checkout area, the grocery cart, the RGB, the fingers of the shoppers, and the fingers of the checkout counter clerk. The study also collected a series of negative controls such as the fingers of the volunteer–customers before they entered the store, several surfaces before study initiation, and a noncontacted shopping cart. The samples were processed using the U.S. EPA single-agar layer method (Ohio EPA, 2005) with antibiotics to remove background bacteria. The *E. coli* strain (ATCC #15597) was used to host the MS2 plaque formation. The plates were incubated at 37 °C for 24 hr and then counted for plaques.

FIGURE 2

Average Concentrations of MS2 Surrogate on Surfaces Contacted by the Reusable Grocery Bag or Shopper's Hand in the Grocery Store



PFU = plaque-forming unit; RGB = reusable grocery bag.

Results

This study presents concentrations of the MS2 bacteriophage on varying grocery store surfaces (Table 1). The data are presented with standard measures of central tendency such as the geometric means (GM) to show differences in magnitude, the percentage of the initial inoculum (%I), the number of surfaces sampled (*n*), and the standard deviation (*SD*). Table 1 also presents the log concentration of the MS2 bacteriophage (LC) and a category for the hypothesized exposure route.

Data are summarized for each surface and category per the hypothesized model presented in Figure 1. The far-left box is the initial contaminated RGB, while the far-right box indicates hand-to-face exposure that signifies the end of the exposure route and potential infection. Surfaces are categorized by the order of contact with a contaminated RGB. The category 1 (C1) surfaces include items that come

in direct contact with the RGB and then a shopper's hand. The category 2 (C2) surfaces come in contact with a C1 surface or hand before becoming contaminated. An example of C2 is the clerk's keyboard at the checkout counter, which would not become contaminated until the clerk first touched the contaminated RGB or contaminated food item.

For simplicity, only two contact categories are presented here, as there are hundreds of possible routes of exposure. Some surfaces in Figure 1 were included for continuity (e.g., facial membranes and other RGBs) and not measured during the experiment. The C1 surfaces with direct contact to the volunteer shopper's hand or RGB had higher overall concentrations of MS2 than the C2 surfaces. The hypothesized virus transmission model was largely validated and the only exception was the high concentration on the checkout clerk's hands (Figures 1 and 2).

The highest concentration of 10⁹ PFU/cm² was the RGB seeded in this study. The source customer hands had the second highest concentration at 9.3 x 10⁷ PFU/cm² (or 1.93% of initial inoculum), with the packaged food as the third most contaminated (Figure 2). The initial concentration of 10⁹ PFU/100 cm² is shown in Table 1 with the log concentration of other items in lighter shades of grey. Due to the high concentration in the initial RGB, the lightest shade of grey still represents a relatively high concentration of virus at 10⁴ PFU/100 cm². The initial concentration of 10⁹ PFU/100 cm² represents environmental concentrations of infectious norovirus particles that have been reported as higher than 10⁹ genome copies/g feces (Lee et al., 2007).

The packaged food was sampled on the handle portion of the plastic bag and had a higher concentration of MS2 than unpackaged food. This finding was not statistically

significant ($t = 0.35$, $p = .72$, $df = 17$) but might indicate a higher percent transferability to the plastic from hands and a higher percent recovery from plastic material to the sample swabs. Most packaged food sampled in this study was in typical grocery store packaging: polypropylene fibrous sacks for produce, clear bags made from polypropylene resins or polyethylene terephthalate (PET) for breads and potatoes. All other C2 handles in the three stores were found to have a lower concentration of the bacteriophage surrogate.

The data in Table 1 are presented for all three grocery stores because they were found to be statistically similar; analysis of variation (ANOVA) showed no significant difference in the mean concentrations of MS2 on the seeded RGB across three different stores ($df = 2$, $F = 2.50$, $p = .151$). The samples were collected in the late afternoon to early evening in the three stores to characterize the time with the most customer traffic. The relative humidity (RH) and temperature were typical for the temperate climate zone during the winter visits on December 15, 2012, and February 8, 2016. The RH and temperatures were 64% and 10.6 °C for Ceres, California; 51% and 22.2 °C for Madera, California; and, 74% and 7.8 °C for Atascadero, California (NCDC, 2012).

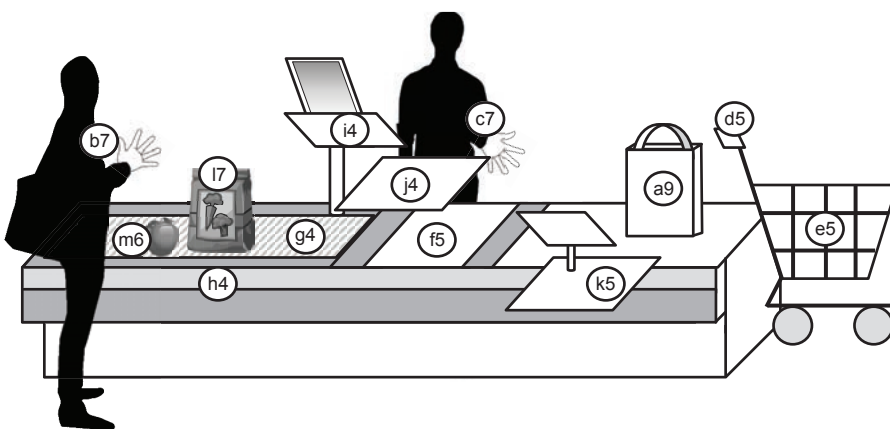
Discussion

The lowest mean concentration of virus detected on a surface was 10^4 PFU/cm². This concentration would represent a virus transmission risk for most individuals encountering any of the surfaces touched by the RGB directly or indirectly through at least one other contact. All C1 and C2 surfaces in the grocery store had detectable MS2, while all control surfaces were appropriately negative or positive. Further study is needed to characterize additional surfaces that were not contacted by the volunteer shoppers.

The high recovery of MS2 from packaged foods could be attributed to the increased adhesion of enteric viruses to hydrophobic PET plastic surfaces (Butot et al., 2007) or similar mechanisms for biofilm adherence within the high density polyethylene (HDPE) pipes (Rozej, Cydzik-Kwiatkowska, Kowalska, & Kowalski, 2015). The surfaces sampled in this study include the polypropylene (PP) fibrous sacks for potatoes and oranges, the clear bags made from PP resins used for table grape bags, unwoven PP sacks

FIGURE 3

Checkout Counter With Contamination Sites Represented by Circles With an Identification Letter and a Number Indicating the Log Concentration of MS2 Surrogate



Note. The letter indicates the surface specified in Table 1 (e.g., e = cart surface). The number abbreviates the log concentration of the MS2 surrogate (e.g., 1×10^5 PFU = 5).

PFU = plaque-forming unit.

From Table 1: Seeded reusable grocery bag = a; customer hands = b; clerk hands = c; cart handle = d; cart surface = e; checkout scale = f; checkout conveyor = g; customer bumper = h; clerk keyboard = i; clerk table = j; customer keyboard and table = k; packaged food = l; unpackaged produce = m.

used in this study for RGBs, and HDPE bags used for self-bagging unpackaged vegetables. Some of these adhesion mechanisms include the material's electrostatic surface charge, the material's hydrophobicity, the influences of temperature and humidity on the material, and other physiochemical parameters within the virus (Langlet, Gaboriaud, Gantzer, & Duval, 2008).

A laboratory study found the attachment of MS2 and noroviruses to polypropylene surfaces to be between 0.1–3% adherence (Deboosere et al., 2012). The referenced MS2 adherence matches well with this current field study that achieved virus concentration recovery ranging from 0.6–1.93% among C1 surfaces (those surfaces that made direct contact with the initial contaminated RGB).

Our study findings are consistent with others who have found that hand washing can be the most important step for customers to reduce their risk of norovirus infection (Hall et al., 2011). The grocery store represents a public area where many individuals mix and touch many common surfaces. A contaminated grocery cart, basket, or RGB

could present the virus transmission pathway hypothesized in this study.

This study develops exposure assessment data that can be used for a quantitative microbial risk assessment (QMRA). More work is necessary to use the QMRA framework on our current dataset to characterize the uncertainty and describe the risk of virus infection from nondietary contact in a grocery store (Figure 1). A similar study used the QMRA framework to determine that the concentration of virus on fomites is the parameter most strongly linked to the estimated dose of the virus to cause a nondietary infection (Julian, Canales, Leckie, & Boehm, 2009).

Conclusion

This study presents various surfaces in the grocery store as potentially contaminated after contact with an RGB containing a surrogate for norovirus. An additional microbial risk assessment should take the data presented in this study and evaluate each surface from a hazard analysis and critical control point (HACCP) perspective. Each of the volunteer shoppers contacted a small percent-

age of available surfaces in each store with one area in common: The checkout stand is touched by every customer. The checkout stand surfaces and the grocery cart present ideal targets for new industry cleaning standards or new materials (Figure 3). This opportunity is also a consideration for small and large grocery stores alike during times of low customer volume because all customers filter through only one checkout stand.

The grocery cart is another surface to target in a HACCP plan, as the virus concentrations were also high. Grocery carts are not contacted as frequently as the checkout stand, and in many climates, are often in the parking lot where they are unintentionally disinfected from exposure to high temperatures, UVA,

and UVC from sunlight. Despite this potential natural process, one study found high concentrations of fecal indicator bacteria on grocery carts collected from stores in Southern California and other metropolitan areas around the U.S. (Gerba & Maxwell, 2012).

This study suggests that a virus-contaminated RGB presents a public health risk if it is brought into a contemporary grocery supermarket. The RGBs are contacted by people, contact many surfaces, and are used to carry a variety of household items in addition to groceries. The bags traverse the hygienic boundaries between private homes and public spaces such as grocery carts and checkout stands.

As the highest concentration of MS2 was found on hands (Figure 3), the health risk

first should be mitigated through promotion of an in-store hand hygiene campaign. The additional surface contamination findings of this report justify additional measures including more frequent surface disinfection with an emphasis on checkout stand surfaces, antimicrobial RGBs, and the use of antimicrobial surfaces to be built into checkout stands. 🐼

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Elevated Blood Lead Levels in Buncombe County Children: Implications of Lowering the North Carolina Intervention Level to the Centers for Disease Control and Prevention Blood Lead Reference Value

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Abstract Public health interventions in North Carolina were implemented only for children with blood lead levels (BLLs) ≥ 10 $\mu\text{g}/\text{dL}$ until the end of the year in 2017, although the Centers for Disease Control and Prevention (CDC) established 5 $\mu\text{g}/\text{dL}$ as a revised reference value for identifying children with elevated BLLs in 2012. This study quantified and characterized the children with elevated BLLs in Buncombe County, North Carolina. A review of case reports of Buncombe County children was conducted through the North Carolina Lead Surveillance System online database. In all, 23 children had confirmed elevated BLLs (≥ 10 $\mu\text{g}/\text{dL}$) from 2005–2015, while 146 children had BLLs within 5 to <10 $\mu\text{g}/\text{dL}$ from 2012–2015. Most of the identified children (62%) lived in Asheville and were 1–2 years old (65%). A significant number of children will be aided and prevented from further lead exposure since North Carolina has lowered the BLL intervention standard to the CDC reference value in 2012. The need for additional staffing at local health departments has been identified to adapt to such change.

Introduction

Lead is among the most common environmental pollutants, and was used in gasoline, water pipes, and lead-based paint, which is the most significant source of lead exposure today in the U.S. (Anna, 2011). Although fatalities due to lead poisoning are rare in modern times, the risk of elevated blood lead levels (BLLs) and the adverse cognitive effects in children due to these exposures is still present (American Academy of Pediatrics, 2005). Children and infants are more vulnerable to lead poisoning due to the immaturity of their organ systems, growing bodies, high gastrointestinal absorption, and frequent hand-to-mouth habits (Cunning-

ham, 2012). As a result of the increased susceptibility of younger populations, impairment in child development occurs and affects cognitive, behavioral, motor, and physical abilities (Binns, Campbell, & Brown, 2007). High BLLs in children have been shown to be associated with decreased IQ (Binns et al., 2007; Lanphear et al., 2005).

Knowledge of potential lead sources is crucial in determining high-risk populations. The three main sources of lead exposure in children in the U.S. are deteriorating lead-based paint, lead-contaminated dust, and lead-contaminated soil (Binns et al., 2007). Most homes built before 1960 and a few built before 1979 were painted with lead-based

paint (Anna, 2011). Moreover, higher rates of lead poisoning were found in geographic areas with higher poverty and/or that have larger minority populations.

When investigating North Carolina, eastern counties that have children with high BLLs were also high-poverty areas with large minority populations (Hanchette, 2008). Many other high-poverty areas in the state, however, were not found to have elevated BLLs in children, indicating that there might be other explanations for higher lead exposures (Hanchette, 2008). Strategies for locating high-risk areas for childhood lead poisoning include selection based on GIS and narrowing down land parcels and neighborhoods based on poverty data and the year homes were constructed (Wilmott, 2009). Such strategies can eventually aid in the risk identification process for health departments and pediatricians (Wilmott, 2009). Considering these factors, lead toxicity in children typically comes from two groups: children living in impoverished conditions and aging homes with poor maintenance, and children from middle- and upper-class families that renovate aging homes without proper anti-contamination measures (Lanphear, 2005).

While the problem has lessened in recent decades, the issue has not vanished as children continue to be exposed to sources of lead. The most recent public health issue related to lead exposure was the contamination of the water supply in Flint, Michigan, exposing thousands of residents and increasing concerns of families for the safety of their children (McLaughlin & Shoichet, 2016). Moreover, recent research showed that BLLs <10 $\mu\text{g}/\text{dL}$ still have effects on childhood

mental and physical development (Binns et al., 2007). In response to this growing evidence, the Advisory Committee on Childhood Lead Poisoning, in conjunction with the Centers for Disease Control and Prevention (CDC), is currently recommending that the level of lead exposure that is to be deemed a risk for children be reduced from the previous 10 µg/dL to 5 µg/dL (Cunningham, 2012). There still exists the consistent need for the promotion and funding of research to further understand the health effects of blood lead levels <10 µg/dL (Binns et al., 2007).

Until the end of the year 2017, North Carolina Department of Health and Human Services (NC DHSS) considered an “elevated blood lead level” confirmed when a BLL was ≥10 µg/dL for two consecutive tests conducted within 6 months (NC DHSS, 1999). BLLs were tested through capillary (i.e., finger prick) or venous blood collection. The specific method of blood collection used, however, was not always indicated in the case records. Once these conditions were met, the local health department advised the child’s guardian and the managing agent of their residence (if applicable) in writing on how to identify potential lead hazards and how to remediate any issues. An investigation from the health department could have been offered at this time, but was not required. If BLLs were consistently >20 µg/dL, however, an investigation became a requirement, as well as remediation. Such interventions can benefit the affected children by preventing further exposure to lead sources.

In 2012, CDC recommended that health departments decrease their intervention level for blood lead from 10 µg/dL to 5 µg/dL. Until the end of the year 2017, the state of North Carolina did not require adaptation to this change, but recommended that children with BLLs >5 µg/dL receive follow-up testing (Norman & Turner, 2012). Thus, since 2012, there are a number of children in Buncombe County with BLLs of 5 to <10 µg/dL who might have benefitted from this change but were excluded from repeat screenings and interventions because North Carolina did not adopt the CDC reference value immediately. North Carolina passed a new state budget in 2017 that allowed for lowering the blood lead intervention level to 5 µg/dL, triggering the investigation and remediation components of the amended state law by January 1, 2018 (Norman, 2017). The

investigation and remediation components are offered and not required for BLLs of 5–9 µg/dL. BLLs of 10 µg/dL or above will require both investigation and remediation. The purpose of this study was to quantify and characterize the children with elevated BLLs (>10 µg/dL) and those with BLLs of 5 to <10 µg/dL in Buncombe County prior to the change in the North Carolina state law.

Methods

Study Participants

Participants in this study were children in Buncombe County, North Carolina, who had existing lead reports available on their cases from 2005–2015. These reports were created in local and/or state records once a child has a detected BLL, and potentially becomes a part of the investigation process depending on several factors (e.g., initial blood lead level, confirmation test results, guardian’s wishes). Buncombe County is located in the western part of the state in the mountainous region. Based on the 2010 census, the population was documented as 238,318 residents, with an estimated 22% of residents being children <18 years old (U.S. Census Bureau, *American FactFinder*, n.d.). Residential locations of children included in the study were Alexander, Arden, Asheville, Barnardsville, Bent Creek, Biltmore Forest, Black Mountain, Candler, Fairview, Leicester, Montreat, Ridgecrest, Royal Pines, Sandy Mush, Swannanoa, Weaverville, and Woodfin.

Data Collection

We collected secondary data on Buncombe County children by reviewing archived lead reports through the Buncombe County Department of Health, the North Carolina Lead Surveillance System (NC LEAD) online database, geographical maps, and other relevant documents from the North Carolina Childhood Lead Poisoning Prevention Program. With the goal of providing direct access to clinical and environmental data related to childhood lead exposure, NC LEAD is a module of the North Carolina Electronic Disease Surveillance System, a component of the web-based surveillance and reporting systems initiative by CDC (NC DHHS, 2017).

The data pool includes all children tested with at least 1µg/dL of lead detected in the blood. Information collected included demo-

graphic data (i.e., age, sex, location of neighborhood residence) and BLLs of these children. Children were categorized based on BLLs (≥10 µg/dL; 5 to <10 µg/dL). Cases with confirmed BLLs ≥10 µg/dL from 2005–2015 were easily identified from the data pool. Due to the tedious process of manually reviewing individual case reports in the NC LEAD database to identify children with BLLs of 5 to <10 µg/dL, however, only records from June 2012 (when CDC changed the blood lead reference value) to October 2015 were reviewed, as the software program we used did not allow data search by “blood lead level” as a parameter but instead could only segregate cases with confirmed BLLs ≥10 µg/dL from the data pool. Data obtained through manual review of individual case reports were manually entered into spreadsheets. Personal identifiers (i.e., name) that could link information to the participants were removed. Permission under HIPAA rules and approval from the East Carolina University Institutional Review Board (approval # UMCIRB 15-00462) were obtained prior to data collection.

Data Analysis

Frequencies and percentages for categorical measures were summarized, while means and standard deviations for continuous measures were determined. Microsoft Excel was used to create worksheets for tabulation and further analysis. Analysis of variance (ANOVA) was conducted to compare mean BLLs by age, sex, and residence location using the online VassarStats statistical software with $p < .05$ considered statistically significant.

Results

Children With Elevated BLLs (≥10 µg/dL) From 2005–2015

We identified 23 children having confirmed elevated BLLs (≥10 µg/dL) from the 2005–2015 database. When confirming an elevated BLL, the lower of the two tests that show BLLs ≥10 µg/dL was designated as the official BLL for the course of the investigation. The average BLL recorded for these children was 14.1 µg/dL, ranging from 10–28 µg/dL. The majority (56.5%, $n = 13$) had BLLs from 10–12 µg/dL, while 30.4% ($n = 7$) had BLLs from 13–15 µg/dL (Figure 1). More than half (56.5%, $n = 13$) of the children were male (Table 1). The average age of children

affected was 19.9 months old. More than half (56.5%) of the children were in the age range of 12–23 months, with an average BLL of 13.92 ± 5.31 $\mu\text{g}/\text{dL}$ (Table 1). The majority of these children (52.2%) were located within the city limits of Asheville, followed by Black Mountain (17.5%), and Arden (8.8%). Neighborhood locations categorized under “other” included Candler, Leicester, Swannanoa, Weaverville, and one unrecorded, with each location having one child with confirmed elevated BLLs (Table 1). No significant differences were found in average BLLs by sex ($p = .44$), age ($p = .23$), or location ($p = .54$).

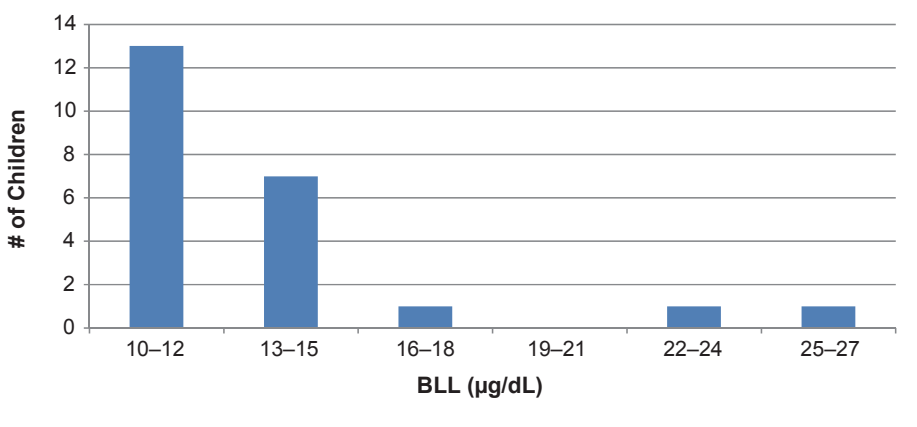
While North Carolina law requires local environmental health departments to follow up on these cases, many have not been able to or have not yet reached conclusion. Although not documented in the database, the reasons that these cases were closed upon attempted follow-up included but were not limited to 1) BLL was within acceptable levels during follow-up blood test, 2) family moved out of the county’s jurisdiction, 3) children aged out of 6-year-old surveillance age, or 4) parent or guardian refused service from the health department. In all, 13 of these cases were closed without conclusion. As of December 2015, four cases were still ongoing due process, and therefore have not yet reached the investigation or communication stage with parent or guardian. Three cases were caused by parental occupation wherein parents were exposed to lead at work and then brought home the lead contaminants, resulting in exposure of the child. One case was found to be due to exposure to peeling lead paint in the area around the home (i.e., play area located immediately outside of the home), while another case was found to be due to peeling paint within the home.

Children With BLLs of 5 to <10 $\mu\text{g}/\text{dL}$ From 2012–2015

We manually reviewed a total of 6,000 NC LEAD records of children with BLLs >1 $\mu\text{g}/\text{dL}$ from June 2012–October 2015 to identify those with BLLs from 5 to <10 $\mu\text{g}/\text{dL}$. Of these reviewed records, 146 (2.4%) had BLLs of 5 to <10 $\mu\text{g}/\text{dL}$, which reflects the number of children who would have received government intervention from the environmental health department from June 2012–October 2015 if the new CDC blood lead reference value had been immediately adapted.

FIGURE 1

Distribution of Children With Elevated Blood Lead Levels (BLLs) (≥ 10 $\mu\text{g}/\text{dL}$) in Buncombe County, North Carolina, by BLL Range, 2005–2015 ($n = 23$)



Out of these 146 children, 63.7% ($n = 93$) were found to be within the city limits of Asheville (Table 2). Specifically, 9 (6.1%) resided in Weaverville, 7 (4.8%) in Black Mountain, 6 (4.1%) in the town of Fairview, and 12 (8.2%) children in “other” residence locations were spread among the small communities of Alexander, Bent Creek, Fletcher, Montreat, Ridgcrest, and Royal Pines (Table 2). Moreover, out of the children with BLLs of 5 to <10 $\mu\text{g}/\text{dL}$, 61% ($n = 89$) were male. The average age of these children was 17.00 ± 7.26 months, or about 1–2 years of age, and their average blood lead level was 5.91 ± 1.27 $\mu\text{g}/\text{dL}$.

Table 3 shows the number, average age, and average BLL of these 146 children by year from 2012–2015. Only the last 6 months of 2012 were studied due to CDC changing their recommended reference value on June 2012. The year with the highest number of children with BLLs of ≥ 5 to <10 $\mu\text{g}/\text{dL}$ ($n = 51$) was 2013, with an average of 4.3 children per month. There was a decreasing trend yearly in the average age of children during this period, while the yearly average BLLs were steady.

Considering the 23 children with BLLs of >10 $\mu\text{g}/\text{dL}$ from 2005–2015 and the 146 children with BLLs of ≥ 5 to <10 $\mu\text{g}/\text{dL}$ from 2012–2015, 169 children would have been the total number of children investigated from 2005–2015 as a result of CDC lowering

the reference value for identifying children with elevated BLLs for government intervention. The average age of these 169 children was 17.4 ± 7.8 months. Table 4 shows the demographic distribution of these children by age, sex, and residence location. The majority of the children (64.5%, $n = 109$) were in the age range of 1–2 years and were male (59.8%, $n = 101$). A majority (62.1%, $n = 105$) were found to be within the city limits of Asheville, followed by 6.5% ($n = 11$) in Black Mountain, and 5.9% ($n = 10$) in Weaverville. The cities with the least number of children were Alexander, Bent Creek, Candler, Marshall, and Ridgcrest, with one child (0.6%) in each city.

Discussion

This study showed that most of the children with elevated BLLs were within the city limits of Asheville. This finding could be attributed to the presence of older homes and apartments within the city limits as a risk factor to lead exposure, as several studies have shown associations between older homes and elevated BLLs (Binns et al., 2007; Kim, Staley, Curtis, & Buchanan, 2002; Whitehead et al., 2014). According to Sperling’s Best Places (2015), the median age of homes in Asheville is 42 years old, which is 5 years older than the median for the U.S. Furthermore, Hanchette (2008) stated that houses built pre-1950 are concentrated in cities and towns, partially

TABLE 1

Average Blood Lead Levels (BLLs) of Children With Confirmed Elevated BLLs (≥ 10 $\mu\text{g}/\text{dL}$) in Buncombe County, North Carolina, by Age, Sex, and Residence Location, 2005–2015 ($n = 23$)

Characteristic	# (%)	Average BLL	p -Value
Sex			.44
Male	13 (56.5)	13.07 \pm 3.64	
Female	10 (43.5)	19.70 \pm 9.83	
Age			.23
<12 months	1 (4.3)	12.58 \pm 0.00	
12–23 months	13 (56.5)	13.92 \pm 5.31	
24–59 months	9 (39.1)	12.56 \pm 2.19	
Location			.54
Asheville	12 (52.2)	12.58 \pm 4.66	
Black Mountain	4 (17.5)	14.00 \pm 1.41	
Arden	2 (8.8)	14.00 \pm 0.00	
Other	5 (21.7)	14.33 \pm 5.13	

TABLE 2

Number of Children With Blood Lead Levels ≥ 5 to < 10 $\mu\text{g}/\text{dL}$ by Residence Location in Buncombe County, North Carolina, 2013–2015 ($N = 146$)

Residence Location	#	%
Asheville	93	63.7
Weaverville	9	6.1
Black Mountain	7	4.8
Fairview	6	4.1
Leicester	5	3.4
Barnardsville	4	2.7
Swannanoa	4	2.7
Arden	3	2.0
Woodfin	3	2.0
Other	12	8.2

explaining the pattern of lead poisoning in these areas with older homes.

Binns and coauthors (2007) reported that among houses built prior to 1940, 68% contain lead hazards; 43% of houses built between 1940–1959 and 8% of houses built between 1960–1977, respectively, contain lead hazards. Moreover, a study by Whitehead and coauthors (2014) found that dust in older homes contained higher levels of lead and other persistent chemicals compared with dust in newer homes.

It must be recognized that at-risk populations not only include children from low-income and/or minority families in older homes but also children from many middle-class families who are moving into historic neighborhoods with older houses that underwent subsequent renovation, including those in ZIP codes considered to be at high risk (Crotty & Eldridge, 2013). Specifically, the Environmental Health Section of the North Carolina Division of Public Health provides a list of all North Carolina ZIP codes in which all children should undergo blood lead screening due to high-risk lead exposure (NC DHHS, 2016).

North Carolina, specifically in Buncombe County, has a need for improved prevention strategies and outreach for lead exposure

prevention among children from families of varying socioeconomic status. Another factor to investigate is the role of day care centers in children's lead exposure, as most of these centers are located within city limits. Risk factors in day care centers are similar to those found in residential properties, including lead-based paint as a potential source in older facilities (Button, 2008). A Cincinnati study by Button found that lead concentrations in the soil within 1.5 m from the exterior walls of day care centers were significantly higher than concentrations found in soil from the remainder of the playground. The same study also found higher lead concentrations in soil at day care centers located closer to interstate highways, which usually are within city limits.

Other possible sources of lead exposure for children located within city limits might also include older schools, libraries, and other building structures, and warrant further investigation. It must be noted, however, that based on 2014 data, 35% of Buncombe County's residents were within Asheville city limits (U.S. Census Bureau, *QuickFacts*, n.d.), which might contribute to the higher proportion of children with elevated BLLs in Asheville.

The age of children with elevated BLLs in Buncombe County was found to be in the

range of 1–2 years old, which agrees with the general understanding that children of early toddling age are at the highest risk of elevated BLLs. Taking this age range as a definitive representation of the age when children are most likely to ingest lead, however, is discouraged because most of the blood lead levels were obtained at milestone birthdays such as 12 and 24 months. BLLs were not monitored continuously in between these milestone ages and, therefore, do not necessarily reflect the age when children begin ingesting lead.

One important finding in this study demonstrates the striking difference between the number of children who benefited from government interventions due to having BLLs ≥ 10 $\mu\text{g}/\text{dL}$ and the number of children who were in the gray area of having BLLs at or above the CDC recommendation of 5 $\mu\text{g}/\text{dL}$ for government intervention, but did not reach the previous North Carolina government intervention level of 10 $\mu\text{g}/\text{dL}$. While there were fewer than 10 children each year with BLLs ≥ 10 $\mu\text{g}/\text{dL}$, there were 30–50 children annually who had BLLs between 5 and < 10 $\mu\text{g}/\text{dL}$. While we did not have complete data from 2015 when this paper was written, the recorded number of children in the range of 5 to < 10 $\mu\text{g}/\text{dL}$ for 2015 was 33. These data demonstrate that there was a need for more

TABLE 3

Number, Average Age, and Average Blood Lead Level (BLL) of Children With BLLs of ≥ 5 to < 10 $\mu\text{g}/\text{dL}$ in Buncombe County, North Carolina, by Year, 2012–2015 (N = 146)

Characteristic	2012 ^a	2013	2014	2015 ^b
Number of children per year	29	51	33	33
Number of children per month	4.1	4.3	2.8	3.3
Age of children (months)	18.1 \pm 6.7	17.5 \pm 7.6	16.9 \pm 7.1	16.7 \pm 6.1
BLL of children ($\mu\text{g}/\text{dL}$)	6.2 \pm 1.4	5.7 \pm 1.1	5.8 \pm 1.2	6.1 \pm 1.4

^aJune–December 2012.
^bJanuary–October 2015.

involvement from the local health department with these 33 children.

Before the amended North Carolina state law, these children in the gray area (i.e., children with BLLs between 5 and < 10 $\mu\text{g}/\text{dL}$) were not recommended to have follow-up blood work and the health department did not contact the families for additional information. Unless they had guardians who were proactive enough in acquiring more information about the children’s current BLLs and researching the implications for themselves, or unless they were fortunate enough to have doctors take notice of these BLLs and review related potential risks and causes, these children could have been exposed to dangerous lead levels with no precautions or interventions.

Several studies have shown that there is no safe BLL in children, and that very low BLLs can negatively affect their behavioral and cognitive functions (i.e., decreased IQ) (Bellinger, 2008; Canfield et al., 2003). Thus, providing interventions to children with BLLs ≥ 5 $\mu\text{g}/\text{dL}$ will prevent further lead exposure and, consequently, reduce both the severity of its health effects and the number of affected children.

It is important to note that local health departments might not have the staff and capability to reach out to children who have BLLs that fall between 5 and < 10 $\mu\text{g}/\text{dL}$. In Buncombe County, at the time of writing, the responsible personnel in the local health department had a full workload in addressing a handful of cases that require intervention annually. As North Carolina lowers the intervention standard to the CDC reference value, in order to be capable of efficiently handling

4–10 times the current workload, additional training of other staff members or hiring additional employees would be necessary to meet a workload that involves more repeat lead screenings.

This increased staffing need was recognized by the state when the law was amended (Norman, 2017). Consequently, purchasing additional equipment (i.e., X-ray fluorescence analyzers) required to detect and quantify lead in paint, toys, and furniture would likely need to be considered, especially if more investigations will be conducted. This equipment can be expensive to purchase and maintain, and thus such equipment is not always readily available. Area county departments must often wait until a state regional specialist with access to such equipment can travel to conduct an inspection with the local health department. The lack of resources, combined with a growing demand from the public, would likely result in lengthy wait times before children can be helped. This delayed intervention would only amplify problems for individual children as they risk continued exposure while they wait for assistance.

As North Carolina implements the changes on the BLL standard, related issues on funding, time constraints, and staffing will need to be addressed by health departments. Conducting a cost-benefit analysis regarding the adaptation to the CDC reference value in Buncombe County and other North Carolina counties will be beneficial, but is not within the scope of this study. The state’s Childhood Lead Poisoning Prevention Program is currently addressing these issues internally as preparations are being made to expand the program’s workload.

TABLE 4

Distribution of Children With Blood Lead Levels Above the Centers for Disease Control and Prevention Recommended Reference Value by Age, Sex, and Residence Location in Buncombe County, North Carolina, 2005–2015 (N = 169)

Characteristic	#	%
Age		
<1 year	7	4.1
1–2 years	109	64.5
3–5 years	53	31.4
>5 years	0	0
Sex		
Male	101	59.8
Female	68	40.2
Residence location		
Asheville	105	62.1
Black Mountain	11	6.5
Weaverville	10	5.9
Fairview	6	3.6
Leicester	6	3.6
Swannanoa	5	3.0
Arden	5	3.0
Barnardsville	4	2.4
Woodfin	3	1.8
Fletcher	3	1.8
Montreat	3	1.8
Royal Pines	2	1.2
Bent Creek	1	0.6
Alexander	1	0.6
Ridgecrest	1	0.6
Candler	1	0.6
Marshall	1	0.6
Unknown	1	0.6

Changes being implemented include increased staffing of environmental health regional specialists (Norman, 2017).

Strengths and Limitations

Findings of this study shed some light on the political, financial, and other implications of lowering the BLL for intervention to the recommended CDC reference value.

This study might be extended to other counties in North Carolina to further determine other factors that can affect the implementation of the change in intervention level. While Buncombe County is an advantageous county to study due to its large size and mix of rural and urban communities, a larger sample would provide a better understanding of children who will benefit from this policy change, as well as the needed resources to implement the policy change. If all 100 North Carolina counties could not be studied due to financial and other constraints, the selection of North Carolina counties to study can be based on certain parameters such rural versus urban, high versus low population, or by regions (i.e., Eastern, Western, and Piedmont).

Several challenges were encountered in collecting data for this study. As the program was in need of updating, the NC LEAD online database offered no simple way to sort entries by BLL or date of screening. The only item available to use to narrow down results was the ability to look at only Buncombe County data instead of the whole state. Therefore, it was necessary to manually collect data by starting at the most recent children tested to have at least 1 µg/dL of BLL, and scroll chronologically to open each child's file one at a time. When this study was conducted,

the program was tailored more for employees who know the exact name or case ID of the child being investigated. It is hoped that with the advancement of the North Carolina Lead Program, the online database will be improved accordingly to become more efficient for government employees in conducting searches and analyses.

Conclusion

This study investigated the number of children in Buncombe County who had confirmed elevated BLLs (≥ 10 µg/dL) in the last 10 years, and children who had BLLs from 5 to < 10 µg/dL since mid-2012. The latter data set was studied to determine the implications of CDC lowering their recommended reference value for BLL for government intervention from 10 µg/dL to 5 µg/dL as applied to North Carolina, specifically to Buncombe County. Toddlers living within the city limits of Asheville were more likely to have the highest risk of lead exposure than children of other ages and residential locations.

A significant number of children will benefit from governmental interventions in preventing further lead exposure as North Carolina lowers the intervention standards to include children with BLLs of 5 µg/dL or more. This study confirmed the need for policy change in North Carolina to stay in

step with the CDC recommendation by revising the standard for government intervention and supports North Carolina's recent policy change. Prior to the change in North Carolina standards, only a small portion of children were aided through local health departments compared with a higher number of children who could have been assisted if standards had been more quickly adjusted to the CDC recommendation.

The recent adaptation of North Carolina to the CDC recommendation will be beneficial to a significant number of children affected by lead exposure. A change of this magnitude, however, will be feasible only if there is also an increase in staffing in local health departments, which entails more financial resources, as already recognized by the state. The results of this study indicate that researchers and policy makers can work together cooperatively to help to protect public health. 🐼

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Building Capacity to Support the Use of Geospatial Modeling for Vectorborne Disease Control: West Nile Virus as a Case Study

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Abstract We surveyed public health and vector control agencies in the U.S. to identify barriers restricting the implementation of geospatial modeling for West Nile virus (WNV) control. We conducted 18 standardized interviews with public health and vector control agencies in states with the highest cumulative human WNV cases. Agencies were organized by their implementation of geospatial modeling (Initial: Implementation and Support; Internal: Surveillance and Mitigation, and External: Outreach and Communication) and thematic analysis was used to identify barriers and best practices. Initial: Implementation and Support agencies reported funding and educational barriers, while Internal: Surveillance and Mitigation agencies reported surveillance data challenges and mistrust of geospatial modeling as limiting geospatial modeling usage. Agencies involved in External: Outreach and Communication reported policy guidelines and lack of public interest as barriers to using geospatial modeling for WNV control. To overcome these challenges, we identified the use of unified resource programs, local data repositories, and multi-stakeholder taskforces for addressing these challenges to WNV control. The findings from this study can be used to help improve WNV control within the U.S. and might be equally valuable for preemptively mitigating the impacts of emerging and reemerging mosquito-borne diseases.

Introduction

The use of geospatial modeling technologies for vector surveillance, control, and prediction has increased rapidly within the last decade. A myriad of geospatial modeling tools implemented in QGIS, R, and ArcGIS have allowed researchers to examine vector presence, abundance, and biodiversity for a variety of vectorborne diseases (VBDs) with respect to time and space (Brown, Diuk-Wasser, Andreadis, & Fish, 2008; Diuk-Wasser, Brown, Andreadis, & Fish, 2005; Eisen & Eisen, 2011; Harrigan, Thomassen, Buermann, & Smith, 2014; Winters et al., 2008).

These advances ideally should allow public health agencies to effectively use limited operational funds, increase their flexibility and response, and improve coordination with other stakeholders. Despite these advances, most public health agencies continue to use

traditional empirical methods of VBD surveillance and control, with limited integration of geospatial modeling techniques to enhance these methods.

The gap between the potential use of geospatial modeling and actual practice for VBD control is evident in the case of West Nile virus (WNV) in the U.S. In response to the emergence and spread of WNV in the U.S. starting in 1999, the Centers for Disease Control and Prevention (CDC) collaborated with public health departments and academic institutions to develop WNV surveillance and mitigation guidelines (CDC, 2000; Gubler et al., 2000).

These guidelines serve as the foundation for a national arbovirus program and outline public health and vector control efforts to monitor WNV infections in humans, birds, mosquitoes, and other vertebrate hosts (Lindsey, Staples, Lehman, & Fischer, 2010). These guidelines continue to be used for WNV control efforts across the U.S., with minor variations dependent on the specific agency features and access to local resources (CDC, 2013).

In addition, the U.S. government has invested significant research dollars to examine factors contributing to the distribution of WNV. For example, within the past five years, the National Institutes of Health (NIH) has invested more than \$250 million aimed at understanding and improving the ability to model and predict WNV transmission (NIH, 2018).

As a result of these studies, a growing body of literature has demonstrated that geospatial modeling techniques can be used to examine a variety of facets, such as the spatial heterogeneity of vectors and hosts and applications into predictive modeling (Brown, Childs,

TABLE 1

Number of Agencies Interviewed and States Included in Each U.S. Region

Region	Agencies Interviewed	States Included
Midwest	5	4
Northeast	2	1
South	4	2
West	7	4
Total	18	11

Diuk-Wasser, & Fish, 2008; Chuang, Hockett, Kightlinger, & Wimberly, 2012; Harrigan et al., 2014; LaBeaud et al., 2008; Morin & Comrie, 2010; Ozdenerol, Taff, & Akkus, 2013). Unfortunately, very little of this progress is reflected within the current CDC WNV surveillance and mitigation guidelines (CDC, 2013).

As CDC guidelines focus primarily on traditional surveillance and mitigation approaches, we hypothesized that a majority of public health and vector control agencies do not optimally use geospatial modeling techniques within their WNV control efforts, and that barriers can prevent further implementation of geospatial modeling efforts. Exploring these factors could provide insights into improving public health practice within this arena. To test this hypothesis, we conducted structured interviews with individuals at public health and vector control agencies in regions of the U.S. with high WNV human cases. We sought to assess how geospatial modeling techniques are currently used to support WNV control efforts, and what barriers might exist to greater use of geospatial modeling for WNV control. Based on our analysis of these interviews, we provide recommendations for how building capacity can expand the use of geospatial modeling capabilities by public health agencies, and how that action could translate into better use of existing funds, improve response to outbreaks, and engender greater support from agencies and stakeholders for vector control activities.

Methods

To focus our efforts in areas with significant WNV burden, we reviewed cumula-

tive human WNV case count data from the 2015 U.S. Geological Survey Disease Maps (CDC, 2018) for each of the 50 states for the 10-year period from 2004–2013. We selected 11 states based on a combination of regional distribution and highest WNV cumulative human case counts (Table 1).

For these 11 states, we used the CDC's county-level ArboNET data to identify counties with the highest WNV human case activity. Within these counties, we identified local public health and vector control agencies involved in WNV-control efforts through a series of Internet searches and agency referrals. In selected counties that lacked local public health or vector control departments ($n = 3$), state-level health departments were included. The resulting agency sampling frame ($n = 22$) consisted of 8 stand-alone public health agencies, 7 stand-alone vector control agencies, and 6 combined vector control/public health agencies. Potential interviewees ($n = 24$) in each of these agencies were identified after speaking with individuals in these departments to identify staff involved in WNV control activities.

Once potential interviewees were identified, they were sent a recruitment e-mail followed by a phone call from a member of the research team. This resulted in an interview pool of 18 individuals representing 7 stand-alone public health departments (both state and local), 6 combined public health and vector control programs, and 5 stand-alone vector control agencies. All interviews were digitally recorded and transcribed using a software program called Transcribe.

The structured interview guide consisted of questions regarding current WNV surveillance and mitigation practices, and specifically, whether their WNV control program used geospatial modeling techniques. For agencies not using geospatial modeling techniques, we asked open-ended questions to elucidate why their agency was not employing these methods and what barriers prevented them from using these tools. Agencies that indicated they were using geospatial modeling techniques were asked additional questions about how their program uses these techniques to enhance their WNV activities.

We analyzed interview data using a qualitative data analysis program called Dedoose, using a thematic analysis approach (Saldaña, 2015). Thematic codes ($n = 91$) were used

to identify underlying concepts that linked recurrent statements about WNV control priorities and challenges, and benefits and barriers with regard to implementation of geospatial modeling techniques. We then refined emergent themes and used a comparative approach across agencies to identify connections between concepts (Saldaña, 2015). The same researchers conducted the coding and analyses to maintain quality consistency and authors discussed thematic coding results for relevancy, followed by further recoding and redefining of appropriate themes.

Results

Based on these interviews, barriers reported by agencies correlate with the category at which the agency was using geospatial modeling for their WNV programs (Tables 2–4). Agencies that were interested in applying geospatial modeling techniques into their WNV program typically described barriers related to the initial implementation and support of geospatial modeling. Agencies that were using geospatial modeling internally for their WNV program generally described barriers related to surveillance and mitigation, while agencies that had already integrated geospatial modeling into their WNV program both internally and externally discussed barriers related to communication and outreach. Below, we examine the main barriers reported within each of these categories.

Initial: Implementation and Support

Individuals from 28% (5/18) of all agencies interviewed reported being in the early stages of geospatial modeling. All but one stand-alone public health agency within this category reported insufficient funding as a primary barrier restricting the application of geospatial modeling within their WNV programs. Individuals reported that the high up-front cost to obtain and maintain software licenses for geospatial programs and geocoding devices prevented their agencies from using geospatial modeling within their WNV programs. Additionally, budgetary constraints related to hiring geospatial modelers were also cited. Furthermore, funding was consistently cited as a barrier among agencies within the later stages of geospatial modeling implementation for their WNV programs.

The second barrier reported by agencies within this category was the high learning

curve required to use geospatial programs. These software programs often require individuals to take multiple courses or tutorials to gain familiarity with the management of geospatial data. Interestingly, this barrier was frequently reported by local public health agencies that were unable to allocate the time and resources necessary for geospatial modeling proficiency. By contrast, the statewide public health agency within this category did not report challenges to learning geospatial software, possibly indicating that more geospatial modeling resources and training opportunities exist at the state level.

Internal: Surveillance and Mitigation

Individuals from 39% (7/18) of the agencies interviewed reported that their agencies were using geospatial modeling for surveillance and mitigation of WNV. All but one of the stand-alone public health departments interviewed expressed challenges associated with using avian surveillance, such as dead bird reporting, as a predictor for identifying WNV risk. Despite literature supporting the use of dead bird surveillance as an early indicator for WNV activity (Eidson, Komar, et al., 2001; Eidson, Kramer, Stone, Hagiwara, & Schmit, 2001; Mostashari, Kulldorff, Hartman, Miller, & Kulasekera, 2003), many agencies reported decreasing utilization of avian surveillance for predicting WNV risk. One particular public health agency adequately explained:

We don't do dead bird surveillance anymore. What ended up happening is that we'd get WNV-positive humans before we would get birds or horses or anything like that. It just wasn't all that useful for us and we've grown out of that.

The decrease in avian surveillance effectiveness could be attributed to several factors, such as increasing avian resistance to WNV (Reed et al., 2009), biases among birds sampled (Ezenwa, Godsey, King, & Guptill, 2006; Foss et al., 2015; Reed et al., 2009), and the decreasing public reporting of dead birds within their neighborhoods (Eidson, Kramer, et al., 2001; Komar, 2006; Mostashari et al., 2003). Additionally, once an area has become endemic for WNV, avian surveillance loses much of its scientific interest and control programs often shift their efforts toward other WNV surveillance mechanisms (CDC, 2017).

TABLE 2

Barriers Reported by Interviewees at Agencies in the Initial Stages of Implementation of Geospatial Modeling (n = 5)

Barrier Reported	Stand-Alone Public Health Agency (n = 4)	Stand-Alone Vector Control Agency (n = 0)	Combined Public Health and Vector Control Agency (n = 1)	Agencies Reporting Barrier (%)
Budgetary constraints	3	NA	1	8
High learning curve	2	NA	1	75

Note. NA indicates that no individuals from this type of agency were placed within this stage of implementing geospatial modeling.

TABLE 3

Barriers Reported by Interviewees at Agencies Already Using Geospatial Modeling for Internal Purposes (n = 7)

Barrier Reported	Stand-Alone Public Health Agency (n = 2)	Stand-Alone Vector Control Agency (n = 2)	Combined Public Health and Vector Control Agency (n = 3)	Agencies Reporting Barrier (%)
Ineffective avian surveillance	1	2	3	86
Spatially incomplete mosquito data	2	2	0	57
View geospatial modeling as research*	2	0	0	29
Home used as proxy for exposure site	0	2	0	29

*Of all stand-alone and combined public health agencies, 39% believed geospatial modeling to be unreliable.

Despite this shift, current CDC WNV guidelines (CDC, 2013) draw attention to the use of the Dynamic Continuous-Area Space-Time (DYCAST) program (Theophilides, Ahearn, Grady, & Merlino, 2003), which uses geospatial modeling of dead bird reports to predict WNV risk. Unfortunately, given the aforementioned problems with dead bird surveillance, the effectiveness of the DYCAST program has decreased over time (Carney et al., 2011), highlighting how existing efforts should be refocused to identify robust data sources for predicting WNV risk.

A second challenge within this category was a perceived inability to conduct geospatial analyses using mosquito surveillance data due to inconsistent spatial coverage. Individuals from both stand-alone public health and vector control agencies within this category believed inadequate mosquito surveillance prevented them from conducting geospatial analyses. This perception is concerning, as a primary strength of geospatial modeling is its ability to help elucidate environmental factors correlated with WNV prevalence in mosquitoes, thereby helping in situations where surveil-

TABLE 4

Barriers Reported by Interviewees at Agencies Already Using Geospatial Modeling for Internal and External Purposes (n = 6)

Barrier Reported	Stand-Alone Public Health Agency (n = 1)	Stand-Alone Vector Control Agency (n = 3)	Combined Public Health and Vector Control Agency (n = 2)	Agencies Reporting Barrier (%)
HIPAA constraints	0	3	0	50
Lack of public trust	1	3	2	50

HIPAA = Health Insurance Portability and Accountability Act.

lance data are incomplete (Brown, Childs, et al., 2008; Chuang, Henebry, et al., 2012; Harrigan et al., 2014; LaBeaud et al., 2008; Morin & Comrie, 2010; Ozdenerol et al., 2013). By contrast, none of the combined public health agencies within this category reported limitations related to using WNV mosquito surveillance data for geospatial analyses.

A third challenge reported within this category was the perception that geospatial modeling is better suited for research. Both the stand-alone public health agencies within this category and 39% (7/18) of all stand-alone and combined public health agencies within this study believed that more advanced geospatial modeling techniques were unreliable and better suited for research purposes than for practice. For example, when questioned if their agency uses advanced geospatial modeling techniques such as predictive mapping of WNV human cases (Rochlin, Turbow, Gomez, Ninivaggi, & Campbell, 2011; Winters et al., 2008), one public health agency stated:

We are the department of health, and we have goals. We don't do research. I think that's a good idea that somebody from academia do it.

Despite this outlook, certain public health agencies have made efforts to predict the risk of WNV transmission to humans (California Department of Public Health, 2017). For example, the California Mosquito-Borne Virus Risk Assessment relies on passive surveillance data to predict overall WNV risk. Similarly, many geospatial modeling techniques also use WNV passive surveillance

data as the basis for their analyses. Still, public health agencies might perceive geospatial modeling techniques to be less reliable for assessing overall WNV risk, despite results being derived from the same data sources. In these cases, the distance between research conducted by public health agencies and academia might be more perceived than real, and future work should try to unify efforts from groups with the same ultimate goals.

The fourth barrier reported within this category were challenges of stand-alone vector control agencies in using the home address of confirmed WNV human cases as a proxy for exposure site. Despite CDC guidelines requiring public health agencies to obtain a 4-week travel and exposure history for cases prior to disease onset, public health agencies typically report the home address of the individual, as people interviewed can be subject to recall bias or simply forget where they were possibly bitten (CDC, 2013; Gubler et al., 2000). One individual from a stand-alone vector control agency in this category explained:

Human cases are tricky when you use the home address because people are very mobile and so they're going from place to place. Unless that person doesn't leave their house, there's a good chance that you won't know where they were exposed, which makes it less reliable for us to use.

While having the home address can be useful for public health outreach programs, the lack of exposure sites can be troublesome for WNV mitigation efforts, as agencies might

be missing potential WNV hotspots. This issue demonstrates an absolute necessity to link human case data with mosquito and avian surveillance (such as through the use of sentinel bird or mark capture-recapture methods), as these combined datasets can allow agencies to confirm legitimate sites or identify "false" hotspots (areas in which only human cases occur, but no present vectors or hosts) in real time (Lange, LaPorte, Talbott, & Chang, 2003; Lange et al., 2004).

External: Outreach and Communication

Individuals from 33% (6/18) of the agencies surveyed reported using geospatial modeling for both internal decision-making and external outreach to stakeholders. Among the agencies represented, two primary barriers were identified: 1) intra-agency communication challenges due to the Health Insurance Portability and Accountability Act of 1996 (HIPAA) and 2) maintaining public interest in WNV activities.

HIPAA-related intra-agency challenges were reported by stand-alone vector control agencies, which receive WNV human case data from stand-alone public health agencies. While HIPAA provides safeguards to protect electronic health information, the Health Information Privacy rule allows for disclosure of health information needed for patient care (U.S. Department of Health and Human Services, n.d.). Stand-alone vector control agencies within this category reported that the spatial level at which positive WNV human cases are reported is at the discretion of their associated public health agency. An individual from a stand-alone vector control agency in this category noted:

Due to HIPAA laws, if someone tests positive for WNV, all I can find out from my local public health department is that it's somewhere in the county. Other departments here have been able to get within a square mile or township range, but it's dependent on how you can get your health department to work with you.

Unfortunately, the specificity of WNV human case locations appears challenging for stand-alone vector control agencies, which must use these data to perform mosquito mitigation. Conversely, both combined and stand-alone public health agencies did not report challenges with communication to stand-alone vector control agencies. This discrepancy suggests

that public health agencies might be unaware of the problems experienced by stand-alone vector control agencies, and that enhanced intra-agency channels of communication are needed for effective WNV control activities.

By contrast, both combined and stand-alone public health agencies reported challenges in maintaining public interest in WNV activity, despite providing real-time WNV geospatial human case data and intensive public health messaging. Despite public projects such as the previously mentioned Disease Maps, public health agencies reported drawbacks to having such data available during observed periods of low WNV presence (Lindsey, Lehman, et al., 2010; Lindsey, Staples, et al., 2010). One individual from a public health agency in this category explained:

People will see that we only have a few cases in our county of WNV one year, even though we [public health] know that it's largely underreported. This reduces WNV as a threat, and people become accustomed to not taking precautionary measures during the WNV season.

To counteract the lack of public WNV preparedness, public health agencies reported spending considerable resources on public education programs, only to be met with disinterest. Lack of public interest in WNV presents a substantial challenge for WNV programs, which must provide WNV control despite declining public interest and decreasing availability of funds.

This trend became a substantial issue during the 2012 WNV season, in which a lack of public interest combined with decreased government spending for WNV contributed to an unprecedented number of WNV human cases ($n = 5,674$) in the U.S. since the initial 1999 WNV outbreak (CDC, 2018).

Furthermore, the 2012 WNV season highlights a larger systematic need for public funds to reflect current public health risks such as WNV. To begin to address these issues, new approaches to public communication might be required in order to balance the fine line between community awareness and message oversaturation, while still bolstering WNV resiliency among communities.

Discussion

To develop recommendations to overcome these barriers, we identified best practices within the interviewed agencies for each of

the three stages of implementation. These recommendations aim to improve the implementation of geospatial modeling efforts for WNV control activities.

Unified Sharing of Geospatial Modeling Resources

Within the Initial: Implementation and Support category, combined public health/vector control agencies reported fewer budgetary and learning constraints compared with stand-alone public health agencies. This finding suggests that stand-alone public health agencies within this category could benefit from uniting with stand-alone vector control agencies within their jurisdictions to share geospatial training and resources (such as hardware).

Additionally, resource sharing would have the co-benefit of fostering more robust intra-agency communication and partnership development. While we recognize that stand-alone public health and vector control agencies have distinct data collection roles with regard to WNV surveillance, unified geospatial training sessions would allow for greater appreciation of the challenges experienced by their partner agencies.

Development of Local Shared Data Repositories

To address barriers related to use of geospatial modeling within the Internal: Surveillance and Mitigation category, agencies would benefit from developing local shared data repositories that include both human and nonhuman WNV surveillance data, similar to CDC's national ArboNET platform (Lindsey, Lehman, et al., 2010). Agencies, however, need access to real-time shared data at a local scale in order to effectively perform geospatial analyses of WNV risk factors. Additionally, increased accessibility to local geospatial WNV surveillance data would increase agency response time and flexibility to changing conditions.

Furthermore, increased application of geospatial modeling can help remove the spatial and resource limitations associated with mosquito surveillance. An abundance of literature supports the use of geospatial modeling techniques to enhance spatial coverage for areas not currently surveyed due to resource or personnel limitations (Anderson, Andreadis, Main, & Kline, 2004; Apperson et al., 2002; Brown, Diuk-Wasser, et al., 2008;

Chuang, Henebry, et al., 2012; Diuk-Wasser, Brown, Andreadis, & Fish, 2006; Harrigan et al., 2014; Liu & Weng, 2012; McFeeters, 2013; Morin & Comrie, 2010; Ruiz et al., 2010; Su, Webb, Meyer, & Mulla, 2003; Sugumaran, Larson, & DeGroot, 2009). Thus, for agencies currently using geospatial modeling for internal purposes, the creation of shared local WNV surveillance data repositories could facilitate optimal use of limited surveillance resources.

Creation of Multi-Stakeholder Taskforces

To address barriers within the External: Outreach and Communication category, we recommend that agencies hold regular meetings of multi-stakeholder taskforces, which include stakeholders associated with WNV control. This best practice was identified among some of the combined public health/vector control agencies:

Funding has been a major gap for us, but through constant communication with the city council, mayor, and commissioner of health, they're providing us assistance and funding and we're trying our best to do what we can for the city.

Multi-stakeholder taskforces are an important mechanism for facilitating partnerships between agencies involved in WNV control and other government agencies that can support these efforts. Additionally, further benefits reported were greater support for WNV spraying initiatives, increased funding, and greater public awareness. More localized planning, transparency, and outreach among agencies can help empower communities to be more vigilant with regard to WNV precautions and emphasize the need for WNV mitigation efforts. Furthermore, regularly scheduled stakeholder meetings can allow for more rapid information transfers, such as for human case data between stand-alone public health and vector control agencies, as well as decrease the reluctance associated with HIPAA constraints.

Limitations and Future Research

We should acknowledge that our analyses on the use of geospatial modeling for vector control had several limitations. First, potential sample bias might be present, as participants were from states with the highest WNV cumulative human case counts for the 2004–

2013 period. Given this factor, participants were likely to be from well-developed WNV programs, which might have influenced their views on the use of geospatial modeling. In this sense, we predict that these examples are ones of a “best-case” scenario, and it is possible that smaller or less funded agencies face these or even greater limitations in their WNV control efforts.

Second, another limitation within our study could be recall bias among the interviewees, which could work for or against the barriers identified in this study. For example, given the number of people in senior positions interviewed, some interviewees might have aggrandized their WNV control programs in a more positive tone for fear of seeming underprepared or outdated. Conversely, given the confidential nature of this study, certain agencies might have overemphasized the extent to which their agencies could be improved (e.g., with the goal of try-

ing to drive more resources nationally to their field of expertise).

Conclusion

This study highlights the barriers facing agencies in implementing geospatial modeling techniques for WNV control. Despite an abundance of literature supporting the use of geospatial modeling efforts for WNV control, the barriers reported by agencies are largely dependent on the category of geospatial modeling used within their agency. These results suggest that stand-alone public health and vector control agencies face the greatest number of barriers in all categories, and that combined public health agencies experience fewer challenges in using geospatial modeling for WNV.

The barriers articulated by agencies and their best practices highlight the need to increase sharing of geospatial modeling resources across agencies, create locally shared repositories of surveillance data, and form regional multi-

stakeholder taskforces to improve communication between agencies and with external stakeholders. These insights provide important ramifications for translating geospatial research into practice to improve the control of WNV. In addition, an increased synergy between modeling and mitigation efforts is likely to improve the prevention of both existing mosquito-borne diseases and newly emerging mosquito-borne diseases such as Zika virus. 🐼

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Did You Know?

As the geographic range of vectors continues to grow and evolve, easily accessible and reliable information on vectors and vectorborne diseases is needed. NEHA has developed a highly informative and interactive web page where visitors can learn about vectors known to be present in their states, as well as view related diseases and surveillance and control methods. Check out the map at www.neha.org/vector-map. This map is phase one of a continuing project. Phase two will provide programmatic resources to help build and improve vector control programs and will be released in summer 2018.



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► BUILDING CAPACITY



Darryl Booth, MBA

Building Capacity Gadget by Gadget

Editor's Note: A need exists within environmental health agencies to increase their capacity to perform in an environment of diminishing resources. With limited resources and increasing demands, we need to seek new approaches to the business of environmental health.

Acutely aware of these challenges, NEHA has initiated a partnership with Accela called *Building Capacity*. *Building Capacity* is a joint effort to educate, reinforce, and build upon successes within the profession, using technology to improve efficiency and extend the impact of environmental health agencies.

The *Journal* is pleased to publish this bimonthly column from Accela that will provide readers with insight into the *Building Capacity* initiative, as well as be a conduit for fostering the capacity building of environmental health agencies across the country.

The conclusions of this column are those of the author(s) and do not necessarily represent the views of NEHA.

Darryl Booth is senior vice president and general manager of environmental health at Accela and has been monitoring regulatory and data tracking needs of agencies across the U.S. for almost 20 years. He serves as technical advisor to NEHA's informatics and technology section.

As a young professional working for a software company and new to environmental health, my boss asked me to exhibit at the National Environmental Health Association's Annual Educational Conference (AEC) & Exhibition. I was anxious and had no idea what to expect. My boss kindly spent some time to describe the event, the exhibition floor, and what to expect. I remember him telling me, "and there's always this guy who sells gadgets, mirrors, thermometers, flashlights,

black lights, etc." Gadgets! Who doesn't love gadgets?

For more than 20 years, I've reflected on those early days as I've prepared for each AEC and regional conference. And more often than not, I've found that table with the red tablecloth that is crowded to the edge with stainless steel devices. It's a perennial favorite and always worth a look.

While LED flashlights and thermal probes are standard fare, there's continued enthusiasm for new digital gadgets.

Must-Have Digital Gadgets

Your mobile phone, for example, is now an indispensable device for communications, navigation, photos, video, quick research, and access to a myriad of cloud-based systems.

For most inspectors, a tablet computer (or laptop) is also essential to capture inspection results in real time, provide canned content (e.g., standard comments), and deliver a professional report to your operator.

Your "mobile office" might also include a Wi-Fi hot spot or even a portable printer.

Compelling Digital Gadgets

Next, we have the gadgets that prompt us to seek new efficiencies and conveniences. These gadgets might not be commonplace, but they are defensible additions.

On a regular basis I am asked about connected thermal probes, and more specifically, thermal probes with a wireless interface to inspection software that can enable an inspector to move quickly down the line and see each measurement automatically recorded. The hardware and wireless connection are commonplace—just Google it—but we still lack a universally accepted data format and transfer standard. Each vendor has its own approach. So, your software vendor or internal information technology department will still have to finish the job and commit to a specific device.

In some regions, dependent upon food codes and policies, a physical inspection report is delivered to retail food operators. It's commonplace for inspectors to carry with them one of the low-cost portable printers currently on the market. These printers

are relatively lightweight, battery powered, rechargeable, and wireless. Unfortunately, the portable printer often stays in the car until the end of the inspection. And carrying the consumables (e.g., special paper) is enough to make many jurisdictions opt to deliver inspection reports as PDFs via e-mail.

Both delivery methods have their devotees. At least one large jurisdiction offers a hybrid. Good inspection findings are sent to operators via e-mail (with copies sent to corporate), while more serious findings are printed and handed to the operator (in addition to the e-mail).

While relying on public Wi-Fi might seem the way to go, most inspectors benefit from built-in connectivity, a mobile Wi-Fi hot spot, or permission to use their phone as a hot spot. This technology is a game changer. With access to the Internet and your cloud data, information moves bidirectionally in a regular, even flow.

Gadgets With Promise

For hunt-and-peck typists, speech-to-text is alluring. The suggestion that one could dictate inspection findings and relevant notes hands-free feels like an ideal arrangement. In a controlled pilot it can work, and it's getting better all the time. Experience and anecdotal evidence have confirmed, however, that inspectors will spend more time tweaking the transcription than they would have saved by avoiding the typing. Today, strict but improving command syntax, coupled with loud work environments and imperfect microphones, make this technology a promising but "not quite there" option.

Video will be a game changer one day soon. Video recordings once produced unwieldy and large files that were unsearchable and difficult to store and transfer. Driven by consumer applications, video is increasingly being generated and stored in the cloud in real time. YouTube, a cloud-based system for receiving, storing, and delivering video,



Photo courtesy of Syda Productions, elearningbrothers.com.

now receives and processes 300 hr of new video every minute!

Google and other providers have invested in automated processes that can transcribe audio content, as well as identify common objects (e.g., a cook surface versus a bathroom fixture), thus making the video searchable by text. Law enforcement can already identify faces from video feeds. Can you imagine how your focus will change when you're wearing a Google Glass or body camera at all times during an inspection? Everything observed becomes a matter of record, making inspector observations automatic and instantly recorded.

This section could go on for pages. Just consider how self-driving cars will impact the field inspector's workday. Then, contemplate how this technology will impact the supply chain, lowering costs and introducing real-time monitoring. It's easy (and fun) to get starry eyed about the future.

How Long Must We Wait?

If environmental health was the only industry pressing for the technology, it could take a very long time. Fortunate for us, the future state is being pushed today by consumers (representing huge financial drivers) and businesses, each seeking gains in personal convenience and reduced costs. In my career, constant Internet access has gone from a theory (remember your bag phone) to an inexpensive reality. In the coming decade, ubiquitous access to cloud-based technology and artificial intelligence will be our new reality.

Continue the conversation in the Building Capacity in Environmental Health Group on LinkedIn (www.linkedin.com/groups/6945520). 🐼

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Did You Know?

New stories have been posted on NEHA's A Day in the Life of an Environmental Health Professional blog. Read about the opioid epidemic, Denver's rapid population growth, food trucks, emergency preparedness, and other interesting topics from members on the blog at www.neha.org/day-in-life-blog.

▶ DIRECT FROM ATSDR

Measuring Community Vulnerability to Natural and Anthropogenic Hazards: The Centers for Disease Control and Prevention's Social Vulnerability Index

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*Agency for Toxic Substances
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Editor's Note: As part of our continued effort to highlight innovative approaches to improve the health and environment of communities, the *Journal* is pleased to publish a bimonthly column from the Agency for Toxic Substances and Disease Registry (ATSDR) at the Centers for Disease Control and Prevention (CDC). ATSDR serves the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. The purpose of this column is to inform readers of ATSDR's activities and initiatives to better understand the relationship between exposure to hazardous substances in the environment, its impact on human health, and how to protect public health.

The conclusions of this column are those of the author(s) and do not necessarily represent the official position of ATSDR or CDC.

Introduction

Until recent decades, the focus of disaster management remained largely on attributes of the physical world, primarily risk assessments of the threat of natural and anthropogenic hazards to the built environment. The concept of social vulnerability within a disaster management context received increasing attention when researchers recognized that a more complete assessment of risk must also include the socioeconomic and demographic factors that affect community resilience (Flanagan, Gregory, Hallisey, Heitgerd, & Lewis, 2011; Juntunen, 2005).

All regions of the U.S. have experienced natural and human-caused disasters. The hazards that precipitate these disasters will continue to occur in the future. Hazards can be large scale, such as hurricanes and earthquakes, or they

can be relatively localized in extent, such as tornadoes or chemical spills. Although hazard events might be relatively benign, they can culminate in disaster—severe injuries, emotional distress, loss of life, and property damage—to the extent of destroying entire communities. In both the short- and long-term future, disasters can have devastating health, social, and economic consequences for affected areas and their inhabitants.

Our work draws on research that examines vulnerability as a social condition or as a measure of the resilience of population groups when confronted by disaster (Cutter, Boruff, & Shirley, 2003). Social vulnerability is defined in terms of the characteristics of a person or community that affect their capacity to anticipate, confront, repair, and recover from the effects of a disaster. Some examples

of factors that might affect a person's social vulnerability include socioeconomic status, household composition, minority status, and vehicle access. The social vulnerability literature reveals that populations living in a disaster-stricken area are not affected equally (Bolin, 2006). Evidence indicates that the poor are more vulnerable at all stages of a catastrophic event, as are racial and ethnic minorities, children, elderly, and disabled people (Morrow, 1999). Socially vulnerable communities are more likely to experience higher rates of mortality, morbidity, and property destruction, and are less likely to fully recover in the wake of a disaster compared to communities that are less socially vulnerable (Juntunen, 2005).

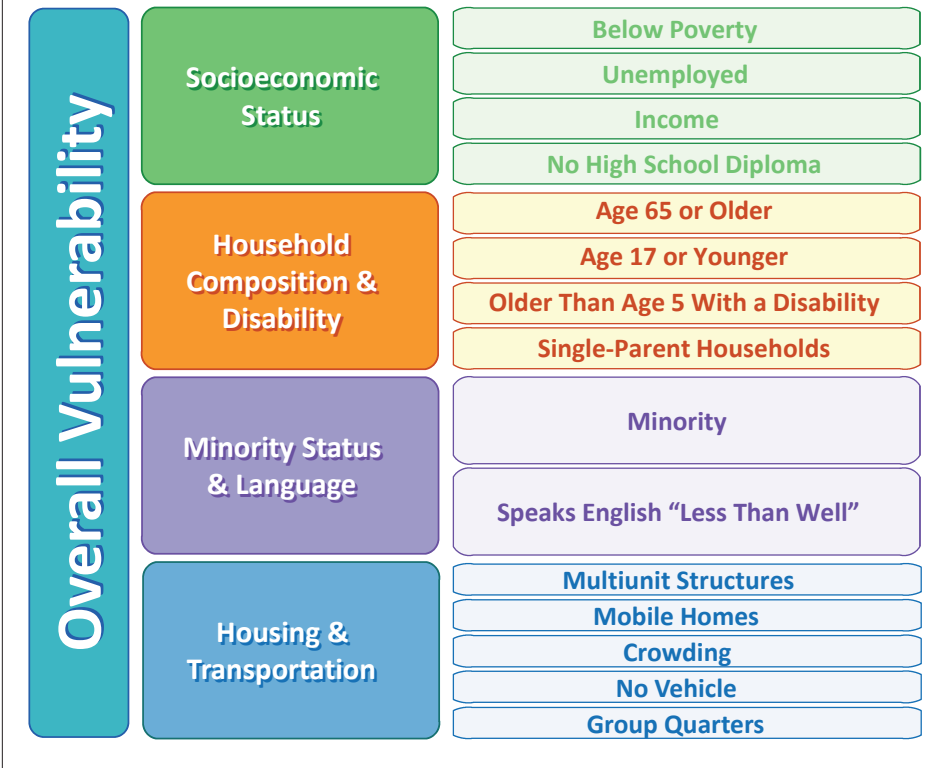
Social Vulnerability Index Database

Pursuant to the Pandemic and All-Hazards Preparedness Act of 2006 that cited public health and medical preparedness and response capabilities as a critical national need, the Geospatial Research, Analysis, and Services Program (GRASP) at Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry created a Social Vulnerability Index (SVI) database and mapping tool designed to assist state, local, and tribal disaster management officials in identifying the locations of their most socially vulnerable populations (Agency for Toxic Substances and Disease Registry [ATSDR], 2018).

To date, GRASP has produced national social vulnerability indices for years 2000, 2010, 2014, and 2016. We constructed the index at census tract level, a geographic scale commonly used to analyze community data for policy and planning in government and

FIGURE 1

Variables and Themes Included in the Social Vulnerability Index Databases



public health (Krieger, 2006). In response to the demand from health department officials, we also provide SVI databases at county level.

Each SVI database comprises 15 census variables, except for the 2010 index as the U.S. Census Bureau did not collect disability data that year (ATSDR, 2018). Each of the census variables was ranked from highest to lowest vulnerability across all census tracts in the nation with a nonzero population. A percentile rank was calculated for each census tract for each variable. The variables were then grouped among four themes (Figure 1). A tract-level percentile rank was also calculated for each of the four themes. Finally, an overall percentile rank for each tract as the sum of all variable rankings was calculated. This process of percentile ranking was then repeated for the individual states.

In a second approach to identifying social vulnerability, we flagged each tract having a variable with a percentile rank ≥ 90 and summed the tract flags to produce counts for each theme and overall. This approach iden-

tifies tracts having a high percentile ranking on one or more variables for which overall vulnerability is masked by other variables having low percentiles.

The mapping of these data (Figure 2) reveals geographic patterns of potential vulnerability to disaster that can be used in all phases of the disaster cycle: preparedness, response, recovery, and mitigation (Morrow, 1999). The SVI database can assist public health officials to better prepare for and respond to emergency meteorological and geological events, disease outbreaks, and human-caused incidents.

SVI Database Use and Validation

The SVI database is used in disaster management by several U.S. state and local governments, as well as several private sector organizations. Examples of studies using the SVI database include

- mapping fire outbreaks and vulnerability metrics to target aid during emergencies (Lue & Wilson, 2017);

- hazard mitigation planning studies (Horney et al., 2017; Horney, Simon, Grabich, & Berke, 2015);
- adult physical inactivity (An & Xiang, 2015; Gay, Robb, Benson, & White, 2016); and
- use of the SVI database, or portions of it, to assess social vulnerability and physical hazards (e.g., sea level rise, flooding, tornadoes, volcanic risk, house fires), hazard awareness, rural/urban differences, migrant and refugee populations, and health status (e.g., youth fitness).

An ongoing GRASP validation effort exists to further clarify the scope and utility of the SVI database. Here we highlight several projects used in our validation effort. A post-Katrina recovery study in New Orleans, Louisiana, found that heavily damaged communities were slow to recover regardless of neighborhood characteristics. Communities with socially vulnerable populations, however, were also slow to recover even without heavy flood damage, and vulnerable communities experiencing heavy damage were slowest to recover (Flanagan et al., 2011). A study in Georgia showed significant spatial clustering and increased rates of extreme heat-related mortality and emergency department visits in areas of high social vulnerability (Adams et al., 2016). Following a series of hurricanes in 2017, the SVI database was applied to media reported mortality data to better understand hurricane-related deaths (Lavery, 2017). A study coupling data from the SVI database with health and environmental data reported the database as a significant predictor of asthma emergency department rates with the strength of prediction varying across counties in the study area (Kolling, Wilt, Berens, Strosnider, & Devine, 2017).

The SVI database has been cited over 100 times in the academic literature (<http://researchgate.net/publication/274439003>). Finally, an independent effort to validate several social vulnerability indices as guides to disaster preparation, recovery, and adaptation finds that the SVI database compares well to other indices, especially with regard to explaining property losses and fatalities (Bakkenen, Fox-Lent, Read, & Linkov, 2017).

Conclusion

Opportunities for expanding the application of the SVI database could include disaster

and nondisaster related uses. The database can be used to examine correlations between aggregate health disparities in communities and potential social barriers to access to care. Forthcoming analyses at the Centers for Disease Control and Prevention aim to identify potential interactions between social vulnerability and environmental burdens faced by communities, including air, water, and soil contamination. Lastly, we believe the SVI database can be productively applied to a myriad of other hazards, threats, and social or health outcomes that communities might encounter in the coming years. 🐾

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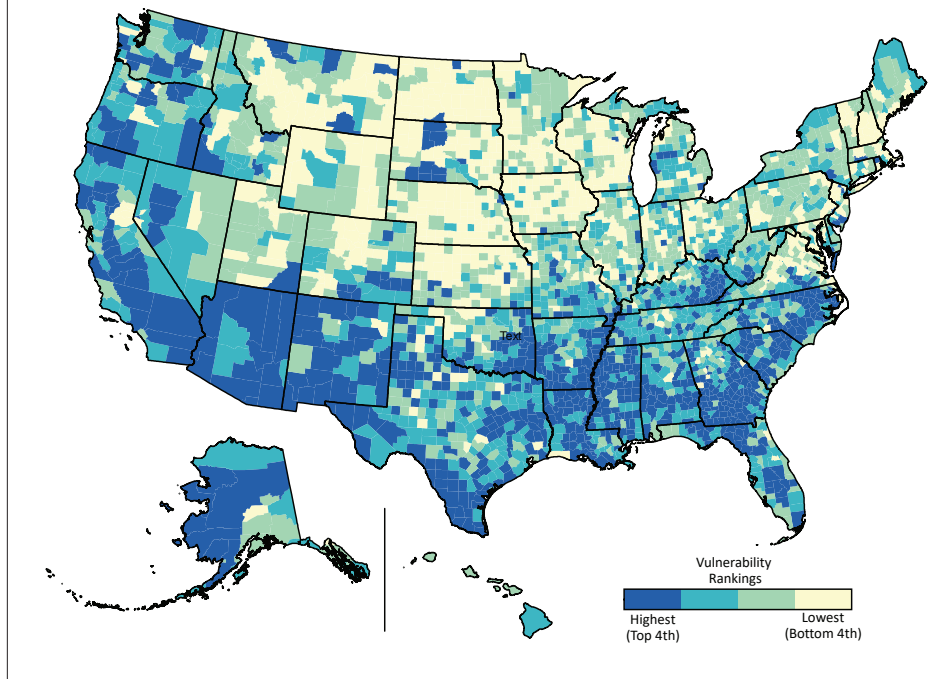
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FIGURE 2

Overall U.S. Vulnerability at County Level as Identified in the Social Vulnerability Index



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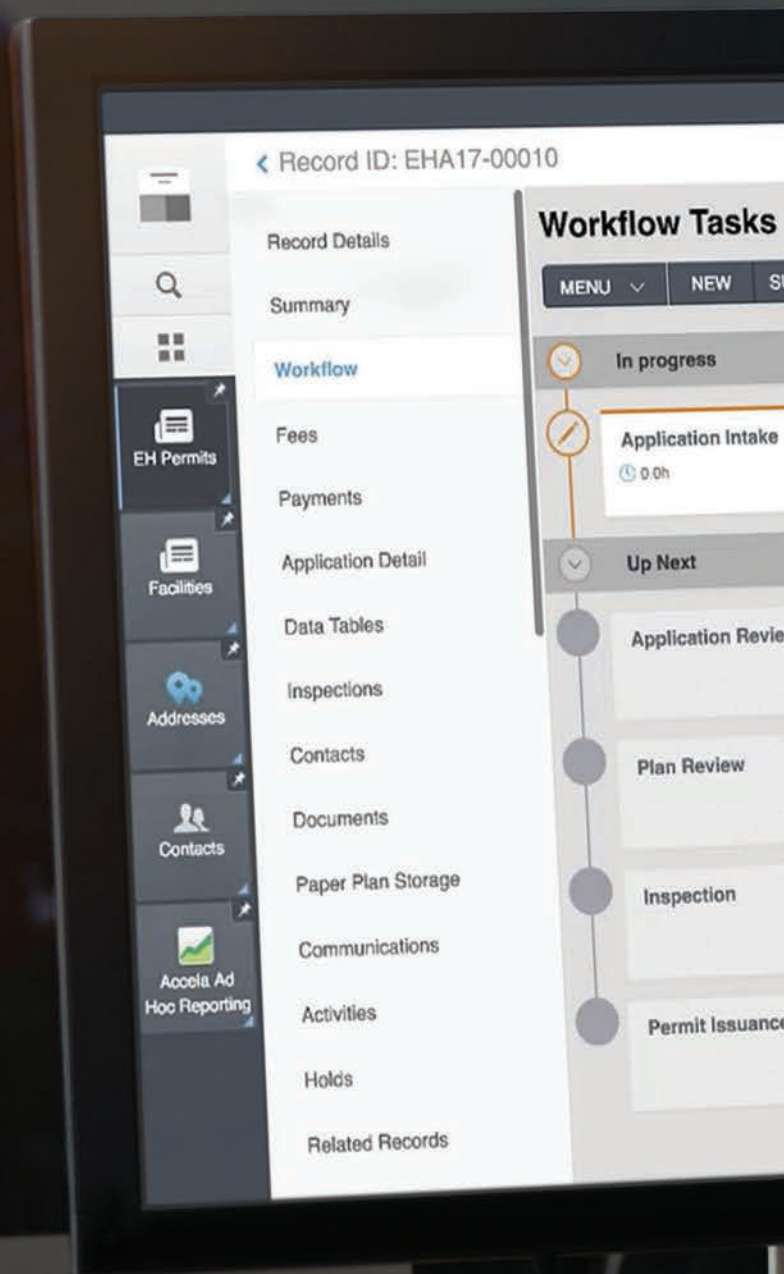
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▶ **DIRECT FROM CDC** ENVIRONMENTAL HEALTH SERVICES

Innovative Safe Water Program Improvement E-Learning for Environmental Health Professionals

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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 this column on environmental health services from the Centers for Disease Control and Prevention (CDC) in every issue of the *Journal*.

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

Introduction

The Centers for Disease Control and Prevention's (CDC) National Center for Environmental Health released a free e-learning curriculum in January 2018 titled Safe Water Program Improvement (SWPI). With approximately 34 million American residents served by privately owned wells (National Ground Water Association, 2016), there is a need for training on how health departments can improve their services to homeowners. CDC developed the curriculum for state, local, tribal, and territorial health departments as a resource to improve safe drinking water programs focused on private wells and other federally unregulated drinking water. CDC designed the SWPI curriculum using the 10 Essential Environmental Public Health Services (EPPHSs) (Figure 1) and the

Environmental Public Health Performance Standards (Centers for Disease Control and Prevention, 2014) as frameworks.

CDC developed the SWPI e-Learning series through a partnership with the National Network of Public Health Institutes (NNPHI); the Texas Health Institute; Tulane University School of Public Health and Tropical Medicine, Center for Applied Environmental Public Health; and the National Environmental Health Association (NEHA). Two environmental health subject matter experts authored the nine courses with continual feedback from all partners. The SWPI e-Learning series uses the latest technology for enhanced learner centric interaction with engaging graphics. The average time to finish each course ranges from 1–2 hr depending on how the learner uses the resources and tools.

Course Highlights

The SWPI e-Learning series is firmly rooted in best public health practices consisting of an introduction and three core public health functions: assessment, policy development, and assurance. The SWPI e-Learning series consists of nine courses that take the learner through lessons and activities following the 10 EPPHSs. Each course lesson has knowledge checks to help the learner understand and apply the content. There are scenarios that help the learner think through and resolve problems using course content. Following a required introductory course, SWPI 101, eight courses cover the 10 EPPHSs (Table 1).

The SWPI e-Learning curriculum employs a “branching role play” technique that presents a complex, real-life example of a public health problem associated with private wells. The courses help the learner to understand how to operationalize the 10 EPPHSs as the problem unfolds. Additionally, learners have the opportunity to access tools and resources to improve partnering, outreach, communications, and research and evaluation skillsets. An engaging graphic from SWPI 104 (Figure 2), shows a methodical approach that the learner can use when developing a health communication plan. Resources linked to this course provide communication examples.

Particularly useful for the learner is how some courses define the role of the environmental health professional in safe water programs focused on federally unregulated drink-

FIGURE 1

The 10 Essential Environmental Public Health Services Wheel



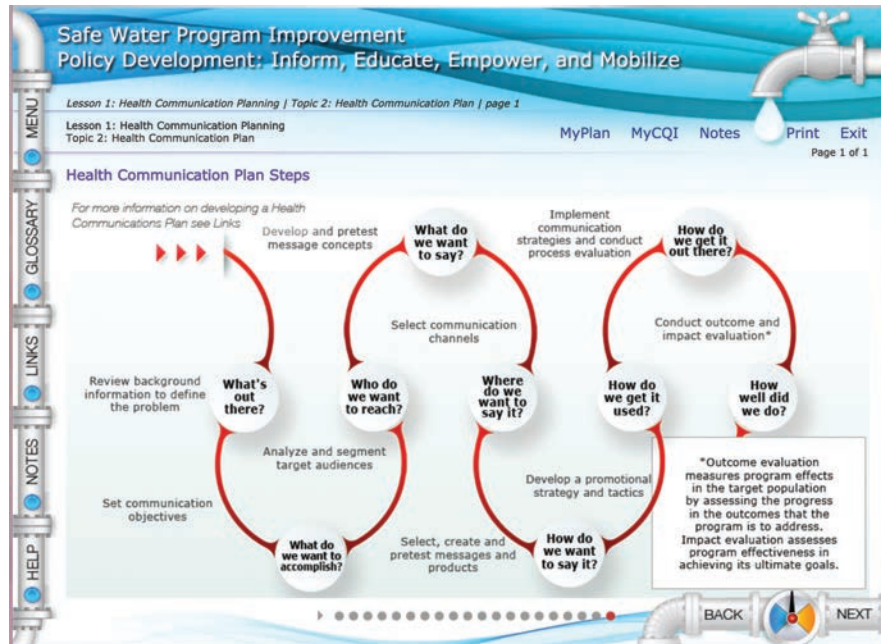
TABLE 1

Safe Water Program Improvement (SWPI) E-Learning Courses and the 10 Essential Environmental Public Health Services

Course #	Core Public Health Function	Course Name
SWPI 101	Introduction	The 10 Essential Environmental Public Health Services and Unregulated Drinking Water Programs
SWPI 102	Assessment	Monitor Health
SWPI 103		Diagnose and Investigate
SWPI 104	Policy development	Inform, Educate, Empower, and Mobilize
SWPI 105		Policies and Plans
SWPI 106	Assurance	Laws and Regulations
SWPI 107		Linking People to Services
SWPI 108		Assuring a Competent Workforce
SWPI 109		Evaluation and Research

FIGURE 2

Example of the Safe Water Program Improvement E-Learning Course Screen on Health Communication Planning



Pilot Tester Feedback

Drinking water and other environmental health staff tested each course in the Safe Water Program Improvement e-Learning series during the pilot testing phase. Of the pilot testers, 9 out of 10 said they would recommend the curriculum to colleagues. One pilot tester commented, "This course will allow me to think more about the sources of unregulated drinking water instead of totally focusing on public sources of water. It will also help me be ready with answers to questions from people using unregulated drinking water sources."

tion, and emphasizes a proactive approach to comprehensive workforce planning

Individuals completing all courses and the final exam will receive a certificate of completion and have the option to receive continuing education credit through NEHA. In addition, the courses are crosswalked with the Public Health Accreditation Board domains and standards that can help programs working towards public health accreditation.

Conclusion

The SWPI e-Learning series provides much needed training at no cost to environmental and public health professionals working

ing water. This component is especially true in the courses addressing policies and plans, and laws and regulations. Another topic for environmental health managers who take the

training is how to maintain and assure a competent workforce. The curriculum also provides content for management and examples that address workforce recruitment and reten-

LEARN MORE

- Steps to Improve Drinking Water Programs: www.cdc.gov/nceh/ehs/safe-watch/steps-to-improve.html
- Safe Water Program Improvement e-Learning Series: <http://lms.southcentralpartnership.org/swpi.php>
- Improving Environmental Public Health Services Performance to Meet Community Needs: www.cdc.gov/nceh/ehs/envphps/docs/improving-eph-serv-perf-comm.pdf

in safe water programs focused on federally unregulated drinking water. The curriculum provides practical and informative examples

of operationalizing the 10 EEPHSs. There are course specific tools and resources to help learners apply their new knowledge in the field and help them improve their own program. The SWPI e-Learning series allows the learner to complete continuing education credit in a convenient, self-paced environment. The courses use a framework and learning approach that will benefit agencies seeking accreditation through the Public Health Accreditation Board. In addition to the references linked to each course, there are tools and resources at CDC's Water, Food, and Environmental Health Services Branch website under the Safe Water section (www.cdc.gov/nceh/ehs) and through NNPHI's Public Health Learning Network (www.nnphi.org/phln). The SWPI e-Learning series is a practical tool for all environmental health professionals interested in improving the performance and quality of their safe drinking water programs. 🌍

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EH CALENDAR

UPCOMING NEHA CONFERENCES

June 25–28, 2018: NEHA 2018 Annual Educational Conference & Exhibition and HUD Healthy Homes Conference, presented by Green & Healthy Homes Initiative, Anaheim, CA. For more information, visit www.neha.org/aec.

July 8–11, 2019: NEHA 2019 Annual Educational Conference & Exhibition, Nashville, TN.

July 13–16, 2020: NEHA 2020 Annual Educational Conference & Exhibition, New York, NY.

NEHA AFFILIATE AND REGIONAL LISTINGS

Alaska

October 17–19, 2018: Annual Educational Conference, hosted by the Alaska Environmental Health Association, Lake Guntersville, AK. For more information, visit www.aeha-online.com.

Colorado

September 18–21, 2018: 63rd Annual Education Conference, hosted by the Colorado Environmental Health Association, Fort Collins, CO. For more information, visit www.cehawe.com.

Florida

July 24–27, 2018: Annual Education Meeting, hosted by the Florida Environmental Health Association, Cape Canaveral, FL. For more information, visit www.feha.org.

Georgia

June 27–29, 2018: Annual Education Conference, hosted by the Georgia Environmental Health Association, Savannah, GA. For more information, visit www.geha-online.org.

Iowa

October 3–4, 2018: Fall Conference, hosted by the Iowa Environmental Health Association, West Des Moines, IA. For more information, visit www.ieha.net.

Montana

September 18–19, 2018: Fall Educational Conference, hosted by the Montana Environmental Health Association, Helena, MT. For more information, visit www.mehawe.com.

Texas

October 22–26, 2018: Annual Education Conference, hosted by the Texas Environmental Health Association, Austin, TX. For more information, visit www.myteha.org.

Utah

September 25–27, 2018: Fall Conference, hosted by the Utah Environmental Health Association, Provo, UT. For more information, visit www.ueha.org/events.html.

Wisconsin

September 19–21, 2018: Educational Conference, hosted by the Wisconsin Environmental Health Association, Onalaska, WI. For more information, visit <https://weha.net/events>.

TOPICAL LISTINGS

Health in All Policies

June 18–20, 2018: Health in All Policies Workshop, sponsored by the World Health Organization, Association of Schools & Programs of Public Health, and National Environmental Health Association, Washington, DC. For more information, visit www.neha.org/health-all-policies-workshop.


Informatics

August 20–23, 2018: 2018 Public Health Informatics Conference, hosted by the National Association of County and City Health Officials and Centers for Disease Control and Prevention, Atlanta, GA. For more information, visit <http://phiconference.org>.

Uniformed Services

June 4–7, 2018: U.S. Public Health Service (USPHS) Scientific and Training Symposium, sponsored by the USPHS Commissioned Officers Foundation for the Advancement of Public Health, Dallas, TX. For more information, visit <http://coausphs.org/events/usphs-symposium>.

Vectors and Pest Control

September 11–14, 2018: 15th International Conference on Lyme Borreliosis and Other Tick-Borne Diseases, hosted by the Centers for Disease Control and Prevention, National Institutes of Health, and National Environmental Health Association, Atlanta, GA. For more information, visit www.neha.org/iclb2018. 

Did You Know?

You can share your event with the environmental health community by posting it directly on NEHA's community calendar at www.neha.org/news-events/community-calendar. Posting is easy (and free) and is a great way to bring attention to your event. You can also find listings for upcoming conferences and webinars from NEHA and other organizations.

Did You Know?

The International Federation of Environmental Health (IFEH), in conjunction with Makerere University Environmental Health Students' Association (MUEHSA), announce the call for abstracts for the 3rd IFEH Academic and 16th MUEHSA Scientific Conference, April 9–11, 2019, in Kampala, Uganda. The conference will bring together practitioners, researchers, academics, policy makers, and students from around the world to discuss recent research findings, developments, best practices, and innovations. Abstract submission is open until June 30. Go to <http://ifehmuehsa2019.musph.ac.ug> for more information.



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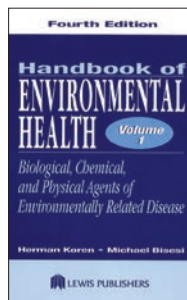
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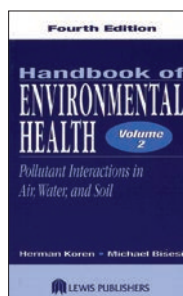
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NEHA NEWS

NEHA's Third App Challenge! Innovating for Environmental Health*By Solly Poprish (spoprish@neha.org)*

In March 2016, the National Environmental Health Association (NEHA), with the support of Hedgerow Software (www.hedgerow-software.com) and Esri, launched its first app challenge—Innovating for Environmental Health. Individuals competed to develop apps that would achieve one of the Healthy People 2020 environmental health objectives as identified by the U.S. Department of Health and Human Services. The mission of the competition was to create apps that could be used by environmental health professionals or the communities they protect, as well as inspire data driven solutions to public health issues.

In summer 2017, we launched the second iteration of the Innovating for Environmental Health App Challenge with continued support from Hedgerow Software. This app challenge was different for a few reasons. First, we chose to focus on a specific environmental health topic: water quality. Second, we partnered with AngelHack, a global hackathon organization that organizes a series of app challenges all around the world that are weekend-long, in-person events bringing together groups of 100–500 developers and tech savvy competitors.

We participated in three events: the first in Los Angeles, California; the second in Detroit, Michigan; and the last in Silicon Valley, California. During these events, NEHA, along with local environmental health professionals, attended to advocate for environmental health and to inspire and guide teams to create apps that can solve water quality issues by utilizing environmental health data. Los Angeles' winning team developed a reporting app that enables users to report location-based data such as water leakage from pipes and spills, which is then translated into reporting format and sent directly to relevant agencies to repair the issues faster. Detroit's winning team utilized U.S. Environmental Protection Agency publicly available water system data to create an app that instantly provides drinking water quality information based on geographic location and the corresponding municipal water system. Both teams attended NEHA's 2017 Annual Educational Conference (AEC) & Exhibition in Grand Rapids, Michigan, where they presented their apps during an education session and received the Innovative App Award at the 2017 AEC Awards Ceremony.

The final winning team from Silicon Valley will attend this year's AEC in Anaheim, California. The winning team created Safe California, a platform and model that easily shares environmental health data to educate and empower residents. The 2018 Innovating for Environmental Health App Challenge is continuing to introduce developers to the environmental health community, and we are seeing the tangible impacts of bringing these two fields together. NEHA will continue its participation in the hackathon series through summer 2018.

Please visit www.neha.org/eh-topics/health-tracking-0/innovating-eh to learn more about the app challenge and see how you can get involved. If you are attending the 2018 AEC, please join us at the Innovating for Environmental Health session to hear from the innovative winners of the competition and to learn about the potential of integrating public data, technology, and environmental health.

NEHA 2018 General Election Results*By Faye Koeltzow (fkoeltzow@neha.org)*

Elections are a critical part of the democratic process and are one way to provide members a voice in the running of their organization. NEHA voting members have an opportunity to vote for candidates of contested board of directors and regional vice-president positions, as well as cast votes regarding proposed Articles of Incorporation and Bylaws changes. National officers of NEHA's board of directors serve a one-year term in each officer position (second vice-president, first vice-president, president-elect, president, and immediate past-president) for a total of five years. Regional vice-presidents serve three-year terms.

Eligible voters were encouraged to vote during the month of March. The deadline to vote was March 31, 2018. The following are results from the 2018 general election.

Articles of Incorporation and Bylaws Changes

By nearly 93% of the vote, NEHA members approved an amendment to the association's bylaws to streamline membership categories from nine to five, as well as remove barriers in the membership criteria. The new categories include professional, emerging professional, retired professional, international, and life.

As an individual member, you will find that the new membership categories are straightforward and inclusive, and will allow for simplicity and ease in your yearly renewal. Students and recent graduates will continue to be recognized with their own membership category (emerging professional), but this category will also be expanded to include anyone who identifies themselves as just starting out in their career.

NEHA believes that our membership categories should reflect the needs of our constituents and today's career paths. The result of this vote demonstrates that making a change to our membership categories will increase the value of membership for many of our current and future members.

NEHA will communicate more details about the changes between now and October 2018 when implementation of the new categories will begin. If you have questions or concerns about the upcoming changes to NEHA's membership, please contact Jonna Ashley, NEHA's membership manager, at jashley@neha.org.

Second Vice-President

There was one qualified candidate for the second vice-president position: Roy Kroeger, REHS. Kroeger ran unopposed and did not

appear on the election ballot. His candidate profile was published in the March *JEH*. Kroeger will assume the second vice-president position at the close of the NEHA 2018 Annual Educational Conference (AEC) & Exhibition and U.S. Department of Housing and Urban Development Healthy Homes Conference in Anaheim, California, in June 2018.

Regional Vice-Presidents (RVPs)

NEHA's membership is broken down into nine regions that represent U.S. geographic areas, as well as members in the U.S. military and abroad. The terms of three RVP positions expire in 2018—Region 2: Keith Allen; Region 3: Roy Kroeger; and Region 8: LCDR James Speckhart.

Regions 2 and 8 had only one eligible candidate and did not appear on the election ballot. Each of these candidates will automatically assume their RVP roles at the 2018 AEC in June 2018. There were two candidates for Region 3 and NEHA members residing in that region were able to vote for the candidates via the election ballot.

The unopposed and elected individuals will assume their positions at the close of the 2018 AEC and their terms will expire in

2021. All candidate profiles were published in the March *JEH*. The new (and returning) RVPs are as follows:

- Region 2: Jacqueline Reszetar, Nevada (Region 2 includes Arizona, California, Hawaii, and Nevada);
- Region 3: Rachele Blackham, MPH, LEHS, Utah (Region 3 includes Colorado, Montana, Utah, Wyoming, and members residing outside of the U.S. [except members of the U.S. armed forces]); and
- Region 8: LCDR James Speckhart, MS, Maryland (Region 8 includes Delaware, Maryland, Pennsylvania, Virginia, Washington, DC, West Virginia, and members of the U.S. armed forces residing outside of the U.S.).

A listing of current NEHA national officers and RVPs, along with state breakdowns for each region, can be found on page 50. More information about NEHA's governance, including its Articles of Incorporation and Bylaws, the election process, and associated deadlines, can be found at www.neha.org/about-neha/governance.

Thank you to all members who participated in this year's election! 🍷

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DirecTalk
continued from page 58

Address Community Environmental Health Problems. Don't miss this one.

While I have described some of the major touchstone sessions, let me be clear, there are plenty of sessions to pique and hold your interest no matter what part of the profession you represent. Some of these sessions include

- Disasters on the Rise: The Centers for Disease Control and Prevention and Harris County Environmental Health Perspective on the 2017 Hurricanes;
- Opioids;
- San Francisco Bay Area Cannabis Foodborne Illness Outbreak Collaborated Response;
- Protecting the Public From West Nile Virus, Zika Virus, and Other Mosquito-Borne Illnesses Through Public Health Collaborations;
- Frequently Asked Questions About Unregulated Drinking Water; and
- Environmental Health and Wildfires.

Finally, a few words about our valued cohosts—the U.S. Department of Housing and Urban Development (HUD) and the Office of Lead Hazard Control and Healthy Homes. We are very excited that they and many of their grantees will be joining us again this year. You may recall that past HUD Secretary



Representative Brenda Lawrence (D-Michigan) addressed attendees at the NEHA 2017 Annual Educational Conference & Exhibition in Grand Rapids, Michigan. Photo courtesy of Casey Stormes, Fresh Look Video.

Julian Castro electrified our 2016 AEC attendees in San Antonio, Texas, and we are hoping that current HUD Secretary Dr. Ben Carson can squeeze us into his schedule to share his vision. There will be an abundant selection of healthy housing and built environment educational sessions from which to choose.

I'd like to finish at the beginning. We will offer several preconference workshops and credential review courses the weekend prior to the conference. We will deliver review courses for our Registered Environmental Health Specialist/Registered Sanitarian, Cer-

tified Professional—Food Safety, and Certified in Comprehensive Food Safety credentials, as well as food safety auditor and instructional skills trainings. The Survival Skills for Environmental Health Leaders Workshop will be hosted by Bob Custard and Dr. Sandra Whitehead. NEHA Membership Director Jonna Ashley will again offer an Affiliate Leadership Workshop intended to provide our state partners with ideas around best practices for small associations. New this year will be our Health Impact Assessment 101 Workshop. These review courses, trainings, and workshops are being offered to ensure that you and your local programs receive technical assistance and training to increase the likelihood of your success.

Bridges, Bonds, and Benefits. Your NEHA staff has collectively spent the last year securing the best talent, national influencers, and thought leaders for our 2018 AEC. We believe in bridges to other health professions. We value creating bonds with the private sector. The benefits of these values and beliefs will pay dividends well into the future. This conference feels right. We hope you are gratified and astonished. 🐼

Dave
ddyjack@neha.org
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David Dyjack, DrPH, CIH

Doing the Right Thing in Anaheim

“Always do right. This will gratify some people and astonish the rest.” Mark Twain had a way with words. Our 2018 Annual Educational Conference (AEC) & Exhibition is a few weeks away, and we, too, feel we have done this one right.

First, the city. In keeping with my commitment to provide a family friendly conference environment, this year we will be in beautiful Anaheim, California. Disney California Adventure Park and Disneyland Park are just one and two miles, respectively, from our host hotel. Mexico is a 90-minute drive away. Newport Beach, Bolsa Chica State Beach, and Laguna Beach are nearby. The site of our annual UL Event, Anaheim's Angel Stadium, is a few blocks away.

We also continue our commitment to affordable food and beverage options within walking distance from the host hotel, as well as within the host hotel. That is, when you need it. On Monday, June 25, the Exhibition Grand Opening & Party will include finger food, and there will be coffee breaks provided to attendees throughout the week. On Wednesday, June 27, the National Restaurant Association is sponsoring the Breakfast & Town Hall Assembly. Finally, we are hosting a special social event—Good Vibrations! Reception—that will feature southern California fare on the evening of Wednesday, June 27. These events and meals are included in all full conference registrations.

While food and location are important, our Chief Learning Officer Kristie Denbrock has canvassed the country to produce a superb educational program. In keeping with our

*This conference
feels right. We hope
you are gratified
and astonished.*

conference theme—Bridges, Bonds, and Benefits—we have enticed some the biggest names in the profession to share their insight and wisdom with you. The opening Keynote Address will feature none other than Frank Yiannas, vice president of food safety and health for Walmart. He will describe private sector efforts to bridge to those of us in the public sector. Yiannas is reportedly a dynamic speaker, and we are pleased that he plans to spend time bonding with our Business & Industry Affiliate.

The Association of State and Territorial Health Officials will convene their annual meeting of state environmental health directors at our AEC for the first time. They will host a panel discussion of state environmental health directors during our Opening Session and have invited Yiannas to join them. The panel will discuss the linkages between federal, state, and local practitioners, as well as how those parties work in concert with the private sector.

We are thrilled and honored to have Rear Admiral Stephen Redd, MD, kickoff our

educational sessions on the second day of the 2018 AEC. Dr. Redd is the director of the Centers for Disease Control and Prevention's Office of Public Health Preparedness and Response. We have met with Dr. Redd several times over recent years to advance conversations around public health emergency preparedness capabilities and the need to create a separate capability for environmental health. I'm personally looking forward to his presentation.

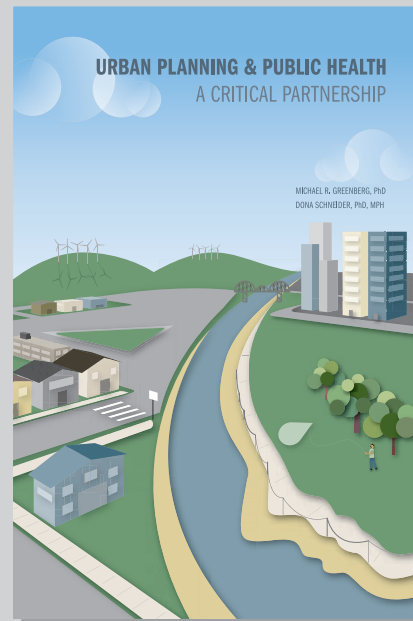
The educational sessions promise to provide you with a menu of fascinating subject matter content. For starters, we received almost 400 abstracts this year, which I understand is a record. We have accepted 280 of those abstracts, which is a lot of content to pack into three days. We will be recording select high-demand sessions for those of you who may be concerned about the difficult decision of which session to attend because of scheduling conflicts.

The 2018 AEC Closing Session will be hosted by our friends at the Association of Public Health Laboratories (APHL). As we migrate into an era where big data and informatics are becoming increasingly central to our work, we are delighted that APHL's Executive Director Scott Becker will be present to help us sift through the roles and responsibilities of public health laboratories, their relationship with the environmental health profession, and how we can better collaborate in a madly evolving profession. The title of this session is Opening the Big Black Box: Partnering With Public Health Laboratories to

continued on page 56

Urban Planning and Public Health: A Critical Partnership

By: *Michael R. Greenberg, PhD*
and *Dona Schneider, PhD, MPH*



Urban environments have enormous impacts on the health of populations, presenting public health and planning professionals with real challenges to create the healthiest environment possible. This book prepares public health professionals to participate effectively in the planning process, building positive health outcomes into planning schemes. This book provides real guidance on how to solve these issues, has case studies that show how effective these policies can be.

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Environmental Health and Justice in a Chinese Environmental Model City

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 College of Economics and Management,
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Abstract This article uses township-level mortality registry databases to examine environmental health disparities in Dalian, China, and potential associations with geographic, social, and economic factors. It is the first time that these Chinese databases have been used for research in environmental health. The findings highlight the fact that environmental health risks and benefits of urban development are unequally distributed between urban centers and their suburbs. Consequently, environmental conditions have been drastically degraded in the suburbs. Furthermore, associated death rates and cancer mortality rates (CMR) have increased. A link between high CMR and industrial pollution was discovered through space-time clusters and statistical analyses. In addition, population aging was found to be a factor in understanding the spatial inequalities of cancer and death. This article suggests that Environmental Model Cities should be required to have no negative impact on environmental health in other areas.

Introduction

China has named numerous Environmental Model Cities as exemplary national models of sustainability (Liu, L., 2008; Ministry of Ecology and Environment, 2015). To improve conditions in the urban core areas, these cities have been relocating polluting industries to nearby suburbs and rural villages, creating new environmental health problems (Liu, L., 2012, 2013). These problems are the result of many interrelated social-economic-political factors (Gee & Payne-Sturges, 2004; Rubin, 2015; Woolf & Braveman, 2011). These problems, however, are often difficult to determine because many environmental health hazards are hidden. Furthermore, it is extremely challenging to demonstrate a causal link between

environmental contamination and human health problems (Tilt, 2013).

Despite this difficulty, numerous attempts have been made to link industrial pollution to cancer (Fischer et al., 2015; Gallagher, Webster, Aschengrau, & Vieira, 2010; Liao et al., 2015; López-Abente, García-Pérez, Fernández-Navarro, Boldo, & Ramis, 2012; Wheeler, Kothencz, & Pollard, 2013). Chinese publications tend to attribute the rising cancer rates to population aging, improved cancer detection technology, and unhealthy lifestyle choices such as smoking. They often do not pay adequate attention to environmental pollution (Xu, Zhang, Lin, Li, & Zhang, 2008; Zhou & Lin, 2010). Nevertheless, Yang and coauthor (2014) were able to map out an association between industrial

water pollution and cancer occurrences in the Huai River Basin of China. Further research in similar areas has been difficult to conduct due to unavailability of data (Holdaway, 2013).

Meanwhile, recent studies have emphasized the growing need to analyze the unequal health impacts of pollution and geostatistical techniques to environmental health research (Beyer, Comstock, Seagren, & Rushton, 2011; Chakraborty, 2012; Luginaah et al., 2012; Metintas, Metintas, Ak, & Kalyoncu, 2012). One article argued for “a spatial turn in health research” along with increasing application of geographic science and technology (Richardson et al., 2013).

Furthermore, geographic differences in cancer mortalities have been found to be related to geographic distances (Sokal, Oden, Rosenberg, & DiGiovanni, 1997). Geospatial data on health and social environments have been used to study health disparities (Richardson et al., 2013). Additionally, researchers have found spatial-temporal cluster analyses to be useful in detecting cancer clusters (Chakraborty, 2012; Luginaah et al., 2012; Rabinowitz et al., 2015; Ren et al., 2016; Riva, Curtis, Gauvin, & Fagg, 2009; Todd & Valleron, 2015; Vieira, Webster, Weinberg, & Aschengrau, 2008; Wheeler, Ward, & Waller, 2012).

Varied findings have been reported in terms of rural-urban health inequalities (Gartner, Farewell, Dunstan, & Gordon, 2008; Gartner, Farewell, Roach, & Dunstan, 2011; McLafferty & Wang, 2009; Singh & Siahpush, 2014). An environmental justice perspective has been increasingly applied when looking at environmental health problems (Liu, L., 2013; Sultana, 2012; Viel, Hägi, Upegui, & Laurian, 2011).

TABLE 1

Changes in Sulfur Dioxide (SO₂) Pollution in Ganjingzi District (Urban Dalian), 2006–2010

SO ₂ Emissions in Ganjingzi	2006	2010	Change (%)
Total SO ₂ discharge (1,000 tons)	493	162	-67
Air concentrations of SO ₂ (mg/m ³)	0.072	0.040	-44
All Dalian manufacturing SO ₂ discharge (%)	55	21	-62

Source: Calculated by authors based on Li, 2011.

TABLE 2

Changes in Cancer Mortality Rate per 100,000, Urban Dalian and Jinzhou, 2006–2009

Year	Urban Dalian	Jinzhou	Jinzhou:Urban Dalian Ratio
2006	195.97	189.91	0.9691
2007	205.51	205.35	0.9992
2008	209.03	214.54	1.0264
2009	208.19	224.60	1.0788

Source: Dalian urban data (Zhou & Lin, 2010); Jinzhou data (Hu & Liu, 2010).

What the expansive environmental health literature lacks, however, is an understanding of the issue in a rural-urban context (Zeng et al., 2015) or from a sustainability perspective. Health, equality, and justice are basic human needs and important components of sustainability. This article uses a sustainability perspective that emphasizes environmental justice to investigate spatial disparities in cancer and death in Dalian, China. We specifically looked into potential ties between cancer and relocated pollution. The focus is on core-periphery (urban-suburban/rural) disparities in three health indicators: death rate, cancer mortality rate (CMR), and percentage of death from cancer (PDC). Current research in China tends to be based on city- and county-level data. Using subcity- and county-level data, this study provides more specific spatial analyses to pinpoint clusters and hot spots of cancer and death.

Study Area, Data, and Methods

Dalian City is located in Northeast China and had a population of 5.94 million in 2014. It includes an urban core area, suburbs, and

outer cities/counties. This study focuses on Jinzhou, a suburban district north of urban Dalian. Jinzhou had a total population of 756,969 in 24 townships by the end of 2013 (see supplemental figure at www.neha.org/jeh/supplemental).

Before 1980, Jinzhou was a traditional agricultural county, with little industrial pollution. As such, it was among China's first accredited Demonstration EcoCommunities in the early 1990s (Ministry of Environmental Protection, 2002). It was well known for its ecoagriculture, namely fruits and vegetables. Jinzhou has received most of the factories relocated from urban Dalian, as well as heavy investment from Dalian and international sources in expanding existing factories and building new ones.

Among the factories, Lynchem Chemical Plant was relocated from Ganjingzi District of urban Dalian to Jinzhou in the 1990s as a farm chemical plant. It continued to expand in size and product types. In 2009, one of its facilities exploded, killing 2 workers and injuring 10. The explosion shattered window glass in nearby villages. About 67 hectares of rice field

nearby were poisoned by the explosion and, since then, has remained fallow. Residents had long complained about health problems and believed that the plant was the culprit.

Relocation includes the relocation of facilities as well as the investments in facilities. The relocation started in the 1990s. The movement of facilities was completed in about a decade or so, but the investment relocation continues. The effects of pollution on health and death are usually delayed. Thus, it is appropriate to study health effects a decade or more after relocation started.

This population-based study used the 2006–2013 mortality and population data in the mortality registry databases of the Jinzhou Center for Disease Control and Prevention (unpublished data). Death refers to deaths from all causes (ICD-10). Cancer means all cancers (C00–C97).

Spatial data included a 1:300,000 digital map of the 24 townships of Jinzhou (unpublished data). As a result of the lack of age- and sex-specific population data, we were unable to calculate the age-standardized mortality rates. Instead, special attention was given to the population aging variable using the percentage of population age 60 years and older. Other variables included birth rate, net income per capita, gross agricultural income per capita, and gross rural industrial income per capita. These were the only variables for which data were available.

ArcGIS10 software was used to build a GIS database of the study area, including geographic location, mortality, and population. Spatial autocorrelation analyses were conducted to detect global and local spatial autocorrelation coefficients, Moran's *I*, using GeoDa0.95i software. The space-time hot spot analyses were conducted using GeoDa0.95i and SaTScan 9.3, following the Bernoulli model with a scan of 25% of the population.

Distance between the Dengshahe River, the factories, and the geometric center of the townships was calculated using ArcGIS10. The 24 townships were divided into urban and rural areas based on the Jinzhou administrative division updated by the 12th Five-Year Plan on Economic and Social Development of the People's Republic of China (Jinzhou New District Government, 2011). Further statistical analyses examined differences between rural and urban townships and their associations with social economic variables using SPSS software.

TABLE 3

Death Rate and Cancer Mortality Rate (CMR) per 100,000 and Percentage of Death From Cancer (PDC), Jinzhou, Dalian, 2006–2013

Year	Death Rate (All Persons)	Death Rate (Male)	Death Rate (Female)	CMR (Total)	CMR (Male)	CMR (Female)	PDC (All Persons)	PDC (Male)	PDC (Female)
2006	620	720	523	171	216	128	28	30	24
2007	621	701	541	183	237	131	30	34	24
2008	644	736	554	183	236	132	28	32	24
2009	651	755	550	189	233	146	29	31	26
2010	642	729	556	186	236	138	29	32	25
2011	636	735	539	191	251	132	30	34	24
2012	675	766	587	191	241	141	28	31	24
2013	664	761	570	190	252	130	29	33	23
Increase 2006–2013	7.19	5.68	8.92	11.28	16.74	1.75	3.81	10.47	-6.58

Source: Calculated from Jinzhou Center for Disease Control and Prevention (unpublished data).

TABLE 4

Global and Local Autocorrelation on Cancer Mortality Rates in Jinzhou, Dalian, 2006–2013

Year	Global Autocorrelation ($p < .05$)			Local Autocorrelation ($p < .05$)		
	Moran's I	z-Score	p-Value	Moran's I	z-Score	p-Value
2006	0.3795	2.6604	.008	0.3795	2.7043	.006
2007	0.5725	3.8708	.002	0.5725	3.9841	.002
2008	0.4750	3.5714	.001	0.4750	3.4148	.001
2009	0.5342	4.0212	.001	0.5342	3.7894	.001
2010	0.2304	1.8168	.049	0.2304	1.8621	.040
2011	0.0683	0.7763	.212	0.0683	0.7180	.241
2012	0.4363	3.2340	.001	0.4363	3.1752	.001
2013	0.3039	2.3342	.012	0.3039	2.1128	.026
Mean	0.4796	3.6015	.002	0.4796	3.5782	.002
Dengshahe River	-0.5155	-4.0283	.001	-0.5155	-4.0592	.001
Lynchem Chemical Plant	-0.4935	-4.0204	.001	-0.4935	-3.9999	.001

Results and Discussion

Disparities in Environmental Health Risks and Benefits Between Urban and Suburban Dalian

The urban parts of Dalian have benefited from the relocation of polluting industries since the early 1990s. Dalian was named one of China's earliest Environmental Model Cities in 1997. In 2001, it was elected to the pres-

tigious ranks of the United Nations Environment Programme (UNEP) Global 500 Roll of Honour for outstanding contributions to the protection of the environment (UNEP, 2001).

UNEP stated that "one outstanding achievement was the relocation of 98 pollution-emitting factories from the City to the suburbs." The 2004–2011 reports from Dalian City Environmental Protection Bureau detailed improvements in environmental condition in

terms of air quality, river and coastal water quality, and pollutant discharges in urban Dalian (Dalian City Environmental Protection Bureau, 2013a, 2013b). Ganjingzi District was the traditional manufacturing zone of urban Dalian (see supplemental figure at www.neha.org/jeh/supplemental). Relocating its polluting industries benefited urban Dalian's environment (Table 1).

Compared with urban Dalian, Dalian's suburbs where the polluting industries were relocated to suffered severe environmental degradation. Along with worsening pollution, Jinzhou lost its blue skies and clean coastal and inland waters. Smog has frequently been reported in Dalian since 10 air quality index (AQI) monitors were installed in 2012. The monitors in Jinzhou, though installed in less polluted spots, display the AQI including $PM_{2.5}$ levels that are often the highest in the Dalian region. In spring 2013, Jinzhou's $PM_{2.5}$ exceeded $500 \mu\text{g}/\text{m}^3$, which was over 7 times that of China's acceptable safe limit of $75 \mu\text{g}/\text{m}^3$ (Liu, Z.Y., 2013), and 20 times that of the World Health Organization's guideline for maximum healthy exposure of $25 \mu\text{g}/\text{m}^3$.

In late December 2014, Jinzhou's $PM_{2.5}$ exceeded $500 \mu\text{g}/\text{m}^3$ for days, reaching $609 \mu\text{g}/\text{m}^3$ at times, compared with $381 \mu\text{g}/\text{m}^3$ in urban Dalian (Zhai & Li, 2014). Dalian City Environmental Protection Bureau found that industrial pollution was the primary cause of the smog, followed by automobile exhaust

TABLE 5

Results of Space-Time Cluster Analyses on Cancer Mortality Rate in Jinzhou, Dalian, 2006–2013

Cluster Tier	Cluster Year	Cluster Center			Radius (km)	# of Communities	LLR	RR	p-Value
		Latitude	Longitude	Community					
1	2009–2012	122.06	39.15	Dalijia	17.36	8	75.62	1.42	<.001
2	2010–2013	121.69	39.26	Daweijia	11.58	6	24.20	1.24	<.001

LLR = logarithmic likelihood ratio; RR = relative risk.

TABLE 6

Descriptive Statistics, Jinzhou, Dalian, 2006–2013

Descriptor	Minimum	Maximum	Mean	SD
Population (all persons)	15,565	91,210	29,547	14,017
Population (male)	7,456	43,312	14,612	6,756
Population (female)	7,831	47,898	14,935	7,267
Birth rate (per 1,000)	3.29	11.53	6.45	1.679
>59 years (%)	5.02	25.83	19	4.933
Male:female ratio	0.88	1.04	0.98	0.028
Net rural income/capita (yuan)	6,174	29,851	16,356	5,282
Gross agricultural income/capita (yuan)	1,344	1,184,259	216,929	149,559
Gross rural industrial income/capita (yuan)	10,215	40,804	20,869	7,771
Distance to river (km)	1.6	34.9	20.8	11.2
Distance to Lynchem Chemical Plant (km)	2.9	37.3	23.6	11.0
Death rate (all persons/1,000)	1.67	12.78	7.17	2.18
Death rate (male/1,000)	1.99	14.55	8.16	2.42
Death rate (female/1,000)	1.37	12.24	6.19	2.09
CMR (all persons/100,000)	48.01	299.55	184.08	47.13
CMR (male/100,000)	67.61	457.44	261.73	71.87
CMR (female/100,000)	18.46	195.02	107.72	39.41
PDC (all persons, %)	13.87	43.65	26.63	5.37
PDC (male, %)	11.39	54.67	33.02	6.92
PDC (female, %)	2.33	36.84	18.24	5.85

CMR = cancer mortality rate; PDC = percentage of death from cancer.

(Min & Li, 2014). The degrading environmental condition is believed to have caused health problems.

Even with limited data, it was still possible to detect changing health conditions between urban Dalian and Jinzhou. Jinzhou had lower CMR than urban Dalian in 2006, and the difference became smaller in 2007 (Table 2). By 2009, Jinzhou's CMR was almost 8% higher than that of urban Dalian. Research suggests that the trend continued and the difference became larger (statisti-

cal data for post-2009 urban Dalian were unavailable for further comparisons).

The mortality registry databases revealed worsening health trends despite fluctuations in rates from 2006–2013 in the 24 townships (Table 3). The death rate increased more than 7% and CMR rose by 11.28% for all persons, reaching 16.74% higher for men. This finding indicates that CMR increased drastically in Jinzhou in recent years. As a result, Jinzhou's PDC for all persons also increased from 2006–2013.

Spatial and Temporal Clusters and Hot Spots Linking to Pollution Sources

Results of space-time cluster analyses indicated that global and local autocorrelation Moran's *I* was statistically significant for the 2006–2013 means and for all individual years except 2011 (Table 4). Local autocorrelation resulted in a high-high clustering, with two neighboring townships, Dengshahe and Dalijia, having high CMRs. A negative correlation existed between the CMRs and distances to the Dengshahe River and the Lynchem Chemical Plant, which were two main pollution sources. An association was determined between cancer mortality and relocated industrial pollution.

The space-time hot spot analyses revealed one tier-one and one tier-two clusters (Table 5; see supplemental figure at www.neha.org/jeh/supplemental). Sources of pollution for the tier-two cluster were unclear. Large-scale garbage dumps and landfill sites with solid waste from urban Dalian and Jinzhou since the 1980s, however, have caused severe air and water pollution (see supplemental figure at www.neha.org/jeh/supplemental).

Dalian has been engaged in one of the largest reclamation projects in China, particularly in Jinzhou (Nanfeng Weekend, 2011). Highways, apartment buildings, factories, and commercial areas have been constructed on the landfill sites. This development benefited urban residents but caused pollution that degraded the ecosystem of the whole western coast of Jinzhou. As a result, aquaculture has all but disappeared. Another possible pollution source likely is the large quantity of pesticides and herbicides that the farmers use increasingly on their fruit trees. It is important to note that both tier-one and tier-two clusters are centered on rural townships, which is an indication that rural areas suffered more severe health problems than urban areas.

TABLE 7

Pearson Correlation Results Between Health and Other Variables, Jinzhou, Dalian, 2006–2013

		Birth Rate	Sex Ratio	Agricultural Income	Population Aging	Distance to River	Distance to Plant
Death rate	All persons	-.436 ^a	.347 ^a	.258 ^b	.830 ^a	-.579 ^a	-.515 ^a
	Male	-.437 ^a	.329 ^a	.244 ^b	.811 ^a	-.562 ^a	-.502 ^a
	Female	-.400 ^a	.334 ^a	.255 ^b	.794 ^a	-.602 ^a	-.533 ^a
CMR	All persons	-.227 ^a	.195 ^b	.245 ^b	.763 ^a	-.533 ^a	-.496 ^a
	Male	-.236 ^a	.132	.241 ^b	.693 ^a	-.565 ^a	-.533 ^a
	Female	-.098	.175 ^b	.121	.564 ^a	-.432 ^b	-.388
PDC	All persons	.374 ^a	-.312 ^a	.153	-.376 ^a	.432 ^b	.343
	Male	.303 ^a	-.300 ^a	.124	-.287 ^a	.290	.202
	Female	.316 ^a	-.209 ^b	.138	-.290 ^a	.609 ^a	.529 ^a

CMR = cancer mortality rate; PDC = percentage of death from cancer.

^aSignificant at the .01 level (2-tailed).

^bSignificant at the .05 level (2-tailed).

TABLE 8

Rural-to-Urban Ratio of Death Rate and Cancer Mortality Rates (CMR) per 100,000 and Percentage of Death From Cancer (PDC), Jinzhou, Dalian, 2006–2013

Year	Death Rate (All Persons)	Death Rate (Male)	Death Rate (Female)	CMR (All Persons)	CMR (Male)	CMR (Female)	PDC (All Persons)	PDC (Male)	PDC (Female)
2006	1.94	1.89	2.17	1.64	1.64	1.60	0.84	0.87	0.73
2007	1.99	1.90	2.11	1.80	1.82	1.69	0.91	0.96	0.81
2008	1.83	1.92	1.93	1.68	1.72	1.62	0.93	0.89	0.84
2009	1.92	1.94	1.89	1.67	1.71	1.58	0.87	0.88	0.83
2010	1.92	1.77	2.13	1.53	1.58	1.41	0.80	0.89	0.66
2011	1.88	1.79	2.02	1.48	1.50	1.38	0.78	0.84	0.68
2012	1.96	1.90	2.03	1.62	1.64	1.61	0.83	0.86	0.79
2013	1.69	1.60	1.82	1.30	1.29	1.33	0.77	0.81	0.73
Mean	1.89	1.83	2.00	1.57	1.60	1.50	0.84	0.88	0.75
China 2006–2013	1.02	1.04	1.00	0.90	0.94	0.83	0.88	0.91	0.84
Jinzhou-to-China ratio	1.85	1.76	2.00	1.74	1.70	1.81	0.95	0.97	0.89

Source: The 2006–2013 averages were calculated from the National Health and Family Planning Commission of China (2015).

Associations of Cancer and Death With Geographic, Social, and Economic Factors

Table 6 shows large variations among the 24 townships in terms of demographic, economic, and mortality variables. We found mortality variables to be correlated to birth rate, sex ratio, and agricultural income per capita (Table 7). In addition, population aging and geometric distances have the highest correlation coefficients. This finding confirms a link between the pollution sources

and health indicators as suggested in the space-time cluster analyses.

To further understand the rural-urban disparities, Table 8 compares the rural and urban townships for their mortality variables. Death rate and CMR were higher in rural than urban areas. The mean CMR was over 50% higher in rural areas than in urban areas, and was 60% higher for the male population. On the other hand, PDC was higher in urban areas than in rural areas, with the rural-to-urban ratio at 0.84:1 for the average of 2006–2013.

Jinzhou's rural-urban disparities in mortality are startling in the Chinese context. The death rate in rural China for the same period was only slightly higher than that in urban China with a ratio of 1:1.02. CMR was actually lower in rural China than urban China with a ratio of 1:0.9. Jinzhou-to-China ratios indicate that Jinzhou's rural-to-urban ratio was higher than the Chinese average by 85% for overall death rate, 100% for female death rate, 74% for overall CMR, and 81% for female CMR (Table 8). This

TABLE 9

Pearson Correlation Results for Rural and Urban Variables, Jinzhou, Dalian, 2006–2013

		Aging	Agricultural Income
Death rate (all persons)	Urban	.913 ^a	.249
	Rural	.348	.444 ^a
Death rate (male)	Urban	.904 ^a	.180
	Rural	.485 ^b	.344 ^b
Death rate (female)	Urban	.846 ^a	.285 ^b
	Rural	.151	.465 ^a
CMR (all persons)	Urban	.799 ^a	.177
	Rural	-.005	.176
CMR (male)	Urban	.769 ^a	.168
	Rural	.027	.196
CMR (female)	Urban	.604 ^a	.110
	Rural	-.058	.069

CMR = cancer mortality rate.
^aSignificant at the .01 level (2-tailed).
^bSignificant at the .05 level (2-tailed).

finding means that environmental health was worse in suburban Dalian than in urban Dalian, and in China as a whole. Pearson correlation results suggest that aging is the variable most linked to mortality in urban townships (Table 9).

In rural areas, it was surprising that agricultural income per capita was positively linked to death rates. This finding might suggest that the higher the income, the higher the death rates, which challenges the notion that rural health has improved along with increased income. It supports the notion that the overuse of pesticides and herbicides might have helped farmer income levels, but at the cost of their health. On the other hand, agricultural income was not linked to CMR. It was also surprising that in rural townships, aging was not linked to death and cancer mortality, except for male death rates.

Further analyses suggest that the trends of death rates and CMR diverge as death rates increase steeply while CMR decelerates, as well as the percentage of population ages 60 years and older increases (Figure 1). The divergence was more visible in urban areas than in rural areas (Figure 1). This finding was possibly because aging in urban areas was relatively low in level and large in range from 5.02–23.3%, as compared with 16.81–26.8% in rural town-

ships. This finding helps us to understand why aging did not correlate with death rate and CMR variations in the rural areas.

Implications to Environmental Health Research and Policies

Our findings support the literature that urban environmental health issues have a strong spatial dimension. Studying this dimension helps reveal possible factors affecting environmental health, and could contribute to the development of appropriate policy measures. It also highlights the importance of applying spatial-temporal cluster approaches to the study of urban environmental health, particularly when distance to polluting sources is a possible factor in explaining variation in environmental health.

These findings reveal environmental injustice during environmental and economic development. The environmental health risks and benefits are unequally distributed between urban and suburban Dalian, as well as between urban and rural Jinzhou, meaning that urban Dalian benefits at the cost of the suburbs. Within Jinzhou, the risks have disproportionately burdened rural townships, which is especially alarming when we consider the fact that rural areas tend to have lower CMRs than urban areas in China

nationwide. This finding contributes to the debate over rural-urban environmental health disparities.

Our findings suggest that the relationship between aging and CMR is not linear. Research indicates that CMR might decelerate or even decline among the very old (de Magalhães, 2013). CMR might also first accelerate and then decelerate with the increasing percentage of aging population as compared with longer life expectancy. Such an outcome has not been reported before and the causes of the outcome are unknown. It is important for health policy makers and practitioners to consider affective measures to deal with the situation, and for health researchers to study the causes of such consequences.

Conclusions

The study demonstrates that urban Dalian achieves environmental health benefits at the cost of suburban and rural areas, which increases the social injustice. Research can benefit from taking a justice perspective in environmental health issues. The findings are useful to urban land use planning and development in China, as well as in other countries.

A similar urban development approach has been used in many other Chinese cities: Shenyang, Changchun, Beijing, Nanjing, Shanghai, and Guangzhou. This article provides a basis for examining how environmental health in these cities has evolved. Environmental Model Cities should be required to refrain from producing a negative impact on environmental health in other areas. Assessment should cover the entire city region (urban, suburban, and rural areas) rather than only urban centers.

The clustering of high CMR townships underscores environmental health disparities that might be overlooked if we pay attention only to the average rates in Dalian or Jinzhou. A link between CMR and polluting sources points to the direction of future work to control pollution in order to improve environmental health. It is interesting that aging might not be linked to CMR when only rural townships are under consideration, because they all have high levels of aging. It is important for health policy makers and practitioners to consider effective measures to deal with this situation, and for health researchers to find out the causes of the deceleration or decline in CMR.

FIGURE 1

Scatter Plots of Correlation Between Aging and Rates of All Deaths and Cancer Deaths in All Townships (A), Urban Townships (B), and Rural Townships (C), Jinzhou District, Dalian, 2006–2013

Rate (1/100,000)



While we have focused on a few variables, it is necessary to note that many other factors affect death and cancer death, such as smoking and diet. Rural residents tend to be affected more by pesticides and herbicides and consume more tobacco than urban people who, on the other hand, tend to be affected more from vehicle pollution. Our understanding is that these factors should be considered when data are available.

Currently, there are no known reports on the effects of these factors in Jinzhou or Dalian. Jinzhou is small in area, so many factors are similar among the townships. Hopefully this article will encourage further research that could include consideration of additional factors. It is also important to note that industrial pollution can cause many kinds of cancers, in addition to general health problems. Some types of cancer, such as lung cancer and stomach cancer, are more directly linked to pollution than others. Further research should examine these types of cancer specifically. 🐼

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