

March/April 2011  
Volume 72, Number 2  
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# NCMJ

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*a journal of health policy analysis and debate*



## Public Health and Environmental Health

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Original articles on asthma care and  
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A review of the National  
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**Annual Subscriptions (6 issues):** Individual, \$42.80 (\$40 plus 7% NC tax); Institutional, \$64.20 (\$60 plus 7% NC tax).

The *North Carolina Medical Journal* is published in January/February, March/April, May/June, July/August, September/October, and November/December. Periodicals postage paid at Morrisville, NC 27560 and at additional mailing offices. **POSTMASTER:** Send address changes to the *North Carolina Medical Journal*, 630 Davis Drive, Suite 100, Morrisville, NC 27560. **Canada Agreement Number:** PM40063731. Return undeliverable Canadian addresses to: Station A, PO Box 54, Windsor, ON N9A 6J5, e-mail: returnsil@imex.pb.com.

**Cosponsors of the North Carolina Medical Journal are The Carolinas Center for Medical Excellence / North Carolina Association of Pharmacists / North Carolina Dental Society / North Carolina Health Care Facilities Association / North Carolina Hospital Association / North Carolina Medical Society**  
Members of these organizations receive the *North Carolina Medical Journal* as part of their membership fees. Additional major funding support comes from **The Duke Endowment**.

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# Tar Heel Footprints in Health Care

*A periodic feature that recognizes individuals whose efforts—  
often unsung—enhance the health of North Carolinians*

## Katherine Shea, MD, MPH



Katherine Shea understands the complexities of health. After she graduated cum laude from the University of Oregon Health Sciences Center and completed residencies in preventive medicine and pediatrics at the University of North Carolina (UNC)-Chapel Hill, Shea worked in pediatric clinical practices and university student health centers for many years. It was during this time that she experienced a life-changing moment. One of her patients underwent a substantial change in behavior, moving from an unhealthy lifestyle to one that fostered good health. Although Shea was pleased by the patient's efforts, the feeling was dampened somewhat by the perceptible decrease in the quality of air around her. In short, Shea realized that the best decisions about personal health will be for naught if concomitant steps are not taken to improve the environment.

With this mind-set, Shea turned her focus toward environmental health and returned to the Gillings School of Global Public Health at UNC-Chapel Hill, to pursue an MPH in environmental sciences and engineering. Shea has since served on numerous environmental health committees, boards, and task forces at the local, national, and international level, including the Intergovernmental Forum for Chemical Safety, the American Academy of Pediatrics National Committee on Environmental Health, the Board of Directors of Toxic Free NC, and the Chapel Hill Sustainable Community Visioning Task Force.

In recent years, Shea focused on climate change, and she became executive director of North Carolina Interfaith Power and Light (NCIPL) in November 2010. NCIPL is a program of the North Carolina Council of Churches and aims to help people of faith understand that climate change is a serious issue being driven by human behavior and that activities that harm the earth are in opposition to what is written in religious texts. Shea has made a substantial impact since arriving. "She has come into what is a fairly complicated organization—managing staff, volunteers, a board of directors, funding, and public policy issues—and has taken the reins fairly quickly and very effectively," remarked George Reed, executive director of the North Carolina Council of Churches. "Her presence has inspired the current leaders within NCIPL to do greater things."

Shea has a deep passion for improving the environment and the health of children, and she has made these issues her life's vocation. When asked what motivates her most to do this work, she explained, "I think we're in deep trouble. I have 2 children who are the light of my life, and I want to be able to say on my deathbed that I did everything I could to help." NCMJ

*Contributed by Anna Bauer, MPH candidate, Department of Maternal and Child Health,  
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# Barriers to Municipal Planning for Pedestrians and Bicyclists in North Carolina

Kelly R. Evenson, Semra A. Aytur, Sara B. Satinsky, Daniel A. Rodríguez

**BACKGROUND** The Guide to Community Preventive Services recommends implementing community- and street-scale urban design, as well as land use policies and practices, to promote walking and bicycling. To better understand barriers to municipal walking and bicycling projects and policies, we surveyed municipal staff in North Carolina.

**METHODS** We surveyed all 121 municipalities with at least 5,000 persons, and 62% responded. We also surveyed 216 of 420 municipalities with less than 5,000 persons, and 50% responded. The municipal staff member most knowledgeable about walking and bicycling planning was asked to complete the survey. Responses were weighted to account for the sampling design, to reflect prevalence estimates for all North Carolina municipalities.

**RESULTS** Common barriers to walking and bicycling projects and policies were selected from a 14-item list. For walking, barriers included lack of funding (93% of responding municipalities), other infrastructure priorities (79%), automobile infrastructure priorities (66%), and staffing challenges (65%). For bicycling, barriers included lack of funding (94% of responding municipalities), other infrastructure priorities (79%), automobile infrastructure priorities (73%), issues were not high priorities for the municipality (68%), staffing challenges (68%), and insufficient support from residents (63%). Barriers generally were more prevalent among rural municipalities than among urban municipalities (9 of 14 barriers for walking and 5 of 14 for bicycling;  $P < .10$ ).

**LIMITATIONS** The study relied on 1 respondent to report for a municipality. Additionally, job titles of respondents varied with municipality size.

**CONCLUSIONS** Health professionals and multidisciplinary partners can assist in overcoming the common local- and state-level barriers to walking and bicycle projects and policies that are reported by North Carolina municipalities.

Walking and bicycling for recreation or transportation contribute to numerous health benefits [1-5]. For example, a meta-analysis of walking found that approximately 8 metabolic equivalent-hours/week (approximately 30 minutes/day for 5 days/week) of walking was associated with a 19% reduction in the risk of coronary heart disease [2]. In another meta-analysis, walking and bicycling for commuting were associated with an 11% reduction in the risk of cardiovascular disease [5]. Other benefits include reductions in the risk of asthma, obesity, diabetes, depression, and some cancers; increases in quality of life; lower carbon emissions and reduced traffic congestion; lower fuel bills and health care costs; and opportunities to reduce health disparities. In addition, areas with facilities for walking and bicycling have higher property values.

Despite the benefits of walking and bicycling, adults and youth in North Carolina often do not reach recommended physical activity levels. In 2009, 17% of North Carolina adults reported any walking or bicycling for transportation, such as to or from work or shopping, during the past week, and 26% reported no leisure activities or exercises during the past month [6], a prevalence similar to the 2009 national average of 24% [7]. By use of a national data source, North Carolina ranked poorly (43rd among states) for the percentage of adults who walked or bicycled for transportation, compared with the rest of the nation [8]. Moreover, for 2005-2007, North Carolina ranked 43rd for walker safety

and 47th for bicyclist safety [8].

The lack of physical activity also extends to North Carolina youth. In 2009, 40% of North Carolina middle school students and 54% of North Carolina high school students did not report at least 60 minutes of physical activity for at least 5 of the previous 7 days [9, 10]. Furthermore, in 2009, among North Carolina middle school students, only 19% reported walking or bicycling to school at least 1 day per week [9]. The burden of physical inactivity and its associated effects on obesity and other health-related conditions [10] generate enormous costs for youth and adults. Billions are spent annually in North Carolina on medical costs, workers' compensation claims, and lost productivity related to these conditions [11], and this is projected to increase with rising obesity [7].

In working to improve physical activity levels, researchers and practitioners increasingly have relied on the ecologic framework [12, 13], which describes how intrapersonal, interpersonal, institutional or organizational, policy, and community or environmental characteristics can influence

Electronically published May 20, 2011.

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**N C Med J.** 2011;72(2):89-97. ©2011 by the North Carolina Institute of Medicine and The Duke Endowment. All rights reserved. 0029-2559/2011/72202

physical activity levels. Traditionally, physical activity interventions have focused on the intrapersonal and interpersonal domains; however, more recently, practitioners have focused on the policy and environmental domains and on interventions that span all levels of the framework. When promoting physical activity to their patients, health care professionals can consider broad policy and environmental contexts in which physical activity occurs. For example, physicians encouraged physical activity in specific locations by writing patients prescriptions to walk that included recommendations of places to go, which involved careful consideration of the environment [14]. In another example pertaining to the environmental context, Estabrooks and colleagues [15] designed an intervention that recruited patients through physician offices and connected them to physical activity resources near their homes and workplaces.

Because physical environments and policies are likely to influence physical activity levels, we surveyed North Carolina municipalities to determine barriers to pedestrian and bicycling projects and policies. We also explored whether these barriers differed between urban areas and rural areas, to inform context-appropriate strategies for individuals working with communities. We surveyed municipalities, rather than counties, since roads outside of municipalities are owned and maintained by the North Carolina Department of Transportation [16].

## Methods

**Sample.** We classified the 541 North Carolina municipalities by their July 2006 population, estimated from 2000 US Census data, and surveyed all 121 municipalities with at least 5,000 persons. From the 420 municipalities with less than 5,000 persons, we drew a random sample of 50%. During 2008, we also collected all North Carolina pedestrian and bicycle plans, as described elsewhere [17, 18]. Smaller municipalities with a pedestrian or bicycle plan were also included in the survey, for a total of 216 municipalities of the possible 420 municipalities with a population of less than 5,000.

**Survey.** For each municipality, the survey targeted the municipal staff member most knowledgeable about walking and bicycling issues. To our knowledge, no comprehensive list of planners or other contact persons exists for all municipalities in North Carolina. Therefore, we used multiple strategies, including the use of planning-association lists, Web site searches, and telephone calls to the municipality, to find the appropriate people to invite to complete the survey. The survey was available by mail and on a Web site in spring 2009. We made several attempts to contact nonresponders.

To assess barriers to walking and bicycling in the community, we asked respondents 2 questions. The first focused on walking: "What barriers do you face in terms of implementing projects, policies, or programs to support walking in your locality?" The question on bicycling was similarly worded. Both had 14 different items for response. The response options for each item included "strongly disagree,"

"disagree," "agree," and "strongly agree," which were collapsed during analysis into "agree" and "disagree." We also reviewed open-ended responses to the "other" category.

**Statistical analysis.** Survey responses were weighted to account for the sampling design and to reflect statewide prevalence estimates for all municipalities. The prevalence is reported using weighting only; as in most cases, the unweighted prevalence was quite similar to the weighted prevalence. We compared survey respondents to nonrespondents, using the Wald  $\chi^2$  test, with US Census data on the municipalities.

To explore differences between rural areas and urban areas, we stratified the results by population size (ie, <5,000 persons vs  $\geq$ 5,000 persons), extending from the process we used to weight the data; the categories are hereafter referred to as "rural" and "urban." When we explored the validity of this definition, we found that 381 (91%) of 420 municipalities with a population of less than 5,000 were classified as rural (ie, they fell outside of the boundary of an urbanized area) on the basis of the 2000 US Census definition [19]. SAS, version 9.2 (SAS Institute), was used for all analyses.

## Results

Among municipalities with a population of at least 5,000 persons, 75 (62%) of 121 responded to the survey. Among municipalities sampled with a population of less than 5,000 persons, 108 (50%) of 216 responded to the survey. Respondents and nonrespondents were not different by region of North Carolina, urban area, percentage of residents who bicycle to work, household income, or income below the poverty level (Table 1). However, respondents were more likely to represent municipalities with a population of at least 5,000 persons and a lower proportion of residents who walked to work, compared with nonrespondents.

Among all respondents, 141 (77%) completed the survey by use of the Web site, and 42 (23%) completed it by use of a paper copy returned via mail. Respondents had been in their current position for a median of 62 months (interquartile range, 31-104 months).

Barriers to implementing walking and bicycling projects and policies are reported in Tables 2 and 3, respectively. Frequently reported barriers to walking projects and policies included lack of funding (93%), other infrastructure priorities (79%), automobile infrastructure priorities (66%), and staffing challenges (65%). Frequently reported barriers to bicycling projects and policies included lack of funding (94%), other infrastructure priorities (79%), automobile infrastructure priorities (73%), issues were not high priorities for the municipality (68%), staffing challenges (68%), and insufficient support from residents (63%). Answers provided in the open-ended response field included other barriers to these projects, such as the challenge of obtaining right-of-way, a need to retrofit roads to accommodate walkers and bicyclists, and inadequate driver education. Policy barriers included language in planning tools or docu-

**TABLE 1.**  
**Characteristics of North Carolina Municipalities That Did or Did Not Respond to the Survey**

Characteristic	Respondents, no. (%) (N = 183)	Nonrespondents, no. (%) (N = 154)	P <sup>a</sup>
<b>Region</b>			
Mountain	28 (15.3)	25 (16.2)	.81
Piedmont	80 (43.7)	67 (43.5)	.97
Coastal	75 (41.0)	62 (40.3)	.89
<b>Population<sup>b</sup></b>			
≥5,000 persons	75 (41.0)	46 (29.9)	
<5,000 persons	108 (59.0)	108 (70.1)	.03
<b>Urban area<sup>c</sup></b>			
Yes	13 (7.1)	5 (3.3)	
No	170 (92.9)	149 (96.7)	.10
<b>Residents aged ≥16 y who, in past week, usually bicycled to work<sup>d</sup></b>			
>0%	71 (38.8)	54 (35.1)	
≤0%	112 (61.2)	100 (64.9)	.48
<b>Residents aged ≥16 y who, in past week, usually walked to work<sup>d</sup></b>			
>16.5%	82 (44.8)	86 (55.8)	
≤16.5%	101 (55.2)	68 (44.2)	.04
<b>Household income<sup>d</sup></b>			
>\$32,279	98 (53.5)	73 (47.4)	
≤\$32,279	85 (46.5)	81 (52.6)	.26
<b>Household income below poverty level<sup>d</sup></b>			
>14.4%	93 (50.8)	76 (49.4)	
≤14.4%	90 (49.2)	78 (50.6)	.79

<sup>a</sup>Calculated by means of the Wald  $\chi^2$  test.

<sup>b</sup>Estimated for July 2006 on the basis of 2000 US Census data.

<sup>c</sup>Defined as areas with a population of ≥50,000 persons, as determined by the 2000 US Census.

<sup>d</sup>Cutpoints are median values for the state and were calculated on the basis of 2000 data from all 541 North Carolina municipalities.

ments, such as ordinances, which limited activities.

For 3 of 14 items, the prevalence of the bicycling barrier was at least 10% higher than that of the walking barrier. Barriers generally were more prevalent among rural municipalities than among urban municipalities (9 of 14 for walking and 5 of 14 for bicycling;  $P < .10$ ). The only exception was the report of lack of funding for bicycle projects, which was higher among urban municipalities, compared with rural municipalities (97% vs 92%).

## Discussion

There are multiple statewide efforts to increase physical activity by creating supportive policies and environments. These include the North Carolina plan to address overweight and obesity in communities [20]; the Eat Smart, Move More NC blueprint for changing environments and policies, to increase physical activity [21]; the North Carolina Institute of Medicine objectives for 2020 [22]; and the North Carolina walking and bicycling long-range transportation plan [23]. Examples of relevant North Carolina health-related projects and collaboratives relevant to these goals are summarized

in Table 4. In support of these statewide efforts, the present study documented barriers to implementing walking and bicycling projects and policies among North Carolina municipalities. We found a high prevalence of many barriers overall and a greater frequency of barriers for bicycling than for walking, as well as a greater frequency for rural areas than for urban areas. The discussion highlights opportunities for health professionals, with regards to these issues.

From the survey list, the most commonly selected barrier for walking and bicycling projects was a lack of funding (93% for walking and 94% for bicycling). In North Carolina, the Transportation Improvement Program (TIP) provides funding for these projects [24]. The TIP is a financially constrained 2-year plan of investments managed by metropolitan planning organizations (MPOs), rural planning organizations (RPOs), and the North Carolina Department of Transportation. In 2008, North Carolina had 17 MPOs (available at: <http://www.ncdot.org/doh/preconstruct/tpb/mpo/mpo.html>) and 20 RPOs (available at: <http://www.ncdot.org/doh/preconstruct/tpb/mpo/rpo.html>). MPOs are federally designated and funded regional institutions that con-

**TABLE 2.**  
**Barriers to Implementing Walking Projects and Policies Among North Carolina Municipalities, Overall and by Population Size**

Barrier	Overall (N = 183)	≥5,000 residents (N = 75)	<5,000 residents (N = 108)	P <sup>a</sup>
<b>Funding and staffing</b>				
There is not enough funding to address these issues	92.6 ± 1.8	94.6 ± 2.1	91.8 ± 2.3	.37
There are staffing challenges to addressing pedestrian issues (eg, not enough staff capacity, staff do not have enough time)	65.3 ± 3.1	52.1 ± 4.8	70.4 ± 3.8	.003
<b>Infrastructure priorities</b>				
Other infrastructure priorities (eg, water, sewer) take precedence over pedestrian issues	79.3 ± 2.6	68.9 ± 4.4	83.2 ± 3.1	.01
Auto infrastructure needs take precedence over pedestrian issues	65.5 ± 3.1	64.9 ± 4.5	65.8 ± 3.9	.88
<b>Community, regional, and state support</b>				
There is not enough support for these issues from regional or state agency officials or policymakers	54.9 ± 3.3	46.5 ± 4.8	58.0 ± 4.1	.07
These issues are not a high-priority topic for my jurisdiction at this time	57.2 ± 3.2	28.2 ± 4.4	67.7 ± 3.8	<.001
There is not enough support for these issues from residents of my jurisdiction	52.1 ± 3.3	23.6 ± 4.1	62.7 ± 4.0	<.001
The local pedestrian needs conflict with regional needs or priorities	35.7 ± 3.2	30.1 ± 4.4	37.8 ± 4.1	.20
There is not enough support for these issues from local agency officials or policymakers (eg, mayor, town manager)	36.0 ± 3.2	17.6 ± 3.6	43.0 ± 4.1	<.001
<b>Land use and development</b>				
The current land use patterns do not support walking	43.4 ± 3.2	44.4 ± 4.8	43.0 ± 4.1	.82
Development pressure makes it difficult to address these needs	34.4 ± 3.2	25.7 ± 4.1	37.8 ± 4.1	.04
<b>Policies</b>				
The policies/regulations specified by other North Carolina state plans do not support walking	26.6 ± 2.9	29.6 ± 4.4	25.4 ± 3.7	.47
The policies/regulations specified by other local plans do not support walking (eg, comprehensive land use plan, subdivision ordinances, transportation plan)	25.9 ± 3.0	9.7 ± 2.8	32.1 ± 3.9	<.001
The policies/regulations specified by other regional plans (eg, RPO/MPO <sup>b</sup> plans) do not support walking	21.9 ± 2.8	13.7 ± 3.3	25.1 ± 3.6	.02

Note. Data are weighted percentage ± standard error.

<sup>a</sup>Calculated by means of the Wald  $\chi^2$  test.

<sup>b</sup>See the Discussion section for definitions of North Carolina metropolitan planning organizations (MPOs) and rural planning organizations (RPOs).

duct transportation planning in all metropolitan areas of the United States. RPOs are transportation planning organizations in North Carolina that provide a forum for rural transportation issues and policies and work in coordination with the state government and the MPOs, though they are not federally mandated. Walking and bicycling projects typically are funded by the “transportation enhancements” funding category, for which law requires that 10% of federal funds under the Surface Transportation Program must be set aside. On the basis of 2004-2008 data, 1.2% of federal transportation dollars were spent on walking and bicycling projects in North Carolina [8].

Secondary sources of money for walking and bicycling projects include a municipality’s budget (eg, funds generated through local bonds and general revenue sources). Another funding option is through the North Carolina Department of Transportation, which administers the portion of the state gas tax that is returned to localities (referred to as State Street Aid or Powell Bill funding). The fund was established to assist municipalities in constructing and maintaining

roadways within their jurisdictions, and, since 1994, it has included the planning, construction, and maintenance of sidewalks and bikeways. Last, private sources and external grants may provide funding for walking and bicycling projects. From our previous analysis of North Carolina pedestrian plans, we found that urban and rural municipalities identified similar funding sources for walking projects [25].

Designing roads to accommodate walkers and bicyclists and, where appropriate, building separate facilities for these users promises to be an effective strategy to increase physical activity among North Carolina residents. In 2007, 60% of North Carolina adults reported that they would be likely to increase their physical activity if their communities had more accessible sidewalks or trails for walking or bicycling [26]. Despite this, approximately two-thirds of the survey respondents selected staffing as a challenge to addressing walking and bicycling issues, and at a prevalence much higher in rural areas than in urban areas. Walking and bicycling issues may be one of many items for which a single staff person in a smaller municipality is responsible. Competing demands

**TABLE 3.**  
**Barriers to Implementing Bicycling Projects and Policies Among North Carolina Municipalities, Overall and by Population Size**

Barrier	Overall (N = 183)	≥5,000 residents (N = 75)	<5,000 residents (N = 108)	P <sup>a</sup>
<b>Funding and staffing</b>				
There is not enough funding to address these issues	93.7 ± 1.6	97.3 ± 1.5	92.4 ± 2.1	.07
There are staffing challenges to addressing bicyclist issues (eg, not enough staff capacity, staff do not have enough time)	68.4 ± 3.0	56.3 ± 4.8	72.9 ± 3.7	.01
<b>Infrastructure priorities</b>				
Other infrastructure priorities (eg, water, sewer) take precedence over bicyclist issues	78.9 ± 2.6	72.6 ± 4.3	81.2 ± 3.2	.11
Auto infrastructure needs take precedence over bicycling issues	72.9 ± 2.9	75.3 ± 4.1	72.0 ± 3.7	.55
<b>Community, regional, and state support</b>				
There is not enough support for these issues from regional or state agency officials or policymakers	50.6 ± 3.2	41.7 ± 4.7	53.8 ± 4.0	.05
These issues are not a high-priority topic for my jurisdiction at this time	68.1 ± 2.9	50.0 ± 4.7	74.9 ± 3.5	<.001
There is not enough support for these issues from residents of my jurisdiction	63.2 ± 3.1	40.3 ± 4.7	71.6 ± 3.7	<.001
The local bicyclist needs conflict with regional needs or priorities	37.3 ± 3.2	42.9 ± 4.8	35.2 ± 3.9	.22
There is not enough support for these issues from local agency officials or policymakers (eg, mayor, town manager)	51.3 ± 3.2	31.1 ± 4.4	58.9 ± 4.0	<.001
<b>Land use and development</b>				
The current land use patterns do not support bicycling	47.0 ± 3.3	43.8 ± 4.7	48.2 ± 4.1	.49
Development pressure makes it difficult to address these needs	41.8 ± 3.2	35.6 ± 4.6	44.1 ± 4.1	.17
<b>Policies</b>				
The policies/regulations specified by other North Carolina state plans do not support bicycling	29.7 ± 3.0	31.4 ± 4.5	29.1 ± 3.8	.69
The policies/regulations specified by other local plans do not support bicycling (eg, comprehensive land use plan, subdivision ordinances, transportation plan)	31.4 ± 3.1	17.8 ± 3.7	36.6 ± 4.0	<.001
The policies/regulations specified by other regional plans (eg, RPO/MPO <sup>b</sup> plans) do not support bicycling	22.3 ± 2.8	16.9 ± 3.6	24.3 ± 3.6	.15

Note. Data are weighted percentage ± standard error.

<sup>a</sup>Calculated by means of the Wald  $\chi^2$  test.

<sup>b</sup>See the Discussion section for definitions of North Carolina metropolitan planning organizations (MPOs) and rural planning organizations (RPOs).

for a staff person's attention create challenges to prioritizing walking and bicycling issues. There is opportunity for health professionals with overlapping interests to provide support.

Approximately two-thirds to three-fourths of respondents agreed that automobile and other infrastructure priorities take precedence over walking and bicycling issues in their municipalities. Additionally, one-half to two-thirds of respondents reported a lack of support for these issues locally, regionally, and at the state level. Bicycling issues garnered less support than walking issues, especially at the local level. Reported lack of support was much higher among rural municipalities than among urban municipalities.

Health professionals are well-positioned to communicate the relationships between environmental attributes, walking and bicycling, and chronic disease with town officials, local policymakers, and community-based organizations, whether in the role of medical experts or as residents. Specifically, they could become members of local commissions on planning, parks and recreation, bicycling, walking, or health. Health professionals could speak at public forums

or join standing committees and provide feedback as plans or policies are proposed or amended. They could bring health to the forefront by identifying the problems of obesity and the lack of physical activity and by championing positive changes [27]. Health professionals could also assist local advocacy groups to become more involved in the municipal or county system, to affect infrastructure priorities and support. They could also consider regional or statewide involvement by working with regional or state departments or advocacy groups, such as those specified in Table 4, to address issues on walking and bicycling.

When asked whether development pressure makes it difficult to address walking and bicycling issues, 34% of respondents answered affirmatively for walking, and 47% answered affirmatively for bicycling. Development pressure in the form of policies that promote sprawl can complicate a local jurisdiction's efforts to address walking and bicycling issues [28]. In Table 5, we describe examples of tools local communities may use to encourage walking and bicycling. They include a mix of strategies, guidelines, and programs

**TABLE 4.**  
**Select Recent Health-Related Programs and Collaboratives in North Carolina That Are Addressing Built Environment and/or Policy Barriers to Walking and Bicycling**

Program	Description	Web site
Communities Putting Prevention to Work	With federal funding from the American Recovery and Reinvestment Act, this project focuses in 11 NC communities and at the state level, to impact active living through the media, access, point of purchase, price, and social support.	<a href="http://www.cdc.gov/CommunitiesPuttingPreventiontoWork/">http://www.cdc.gov/CommunitiesPuttingPreventiontoWork/</a>
Eat Smart, Move More NC	A statewide partnership of more than 60 member organizations dedicated to improving physical activity and diet in NC, to enable residents to move more, eat smart, and achieve a healthy weight. This partnership includes local coalitions and grant programs.	<a href="http://eatsmartmovemorenc.com/">http://eatsmartmovemorenc.com/</a>
Fit Community Program	This initiative was developed by the NC Health and Wellness Trust Fund, in collaboration with Active Living by Design, to recognize and reward NC municipalities and counties that excel in supporting physical activity, healthy eating, and tobacco-use prevention in the community, schools, and workplaces.	<a href="http://www.fitcommunitync.com">http://www.fitcommunitync.com</a>
Healthy Environments Collaborative	This is a collaboration of 4 state departments: Health and Human Services, Transportation, Commerce, and Environment and Natural Resources. The mission is to integrate and influence interdepartmental efforts to improve the health of NC people, environments, and economy.	<a href="http://nchealthyenvironments.com">http://nchealthyenvironments.com</a>
Investigating Places for Active Recreation in Communities	This initiative seeks to advance the science of how parks, recreation, and sport environments promote active living and to facilitate the application of evidence-based policies and practices, to enhance opportunities for physical activity.	<a href="http://cnr.ncsu.edu/iparc/">http://cnr.ncsu.edu/iparc/</a>
NC Action for Healthy Kids	The mission of this program is to improve children's physical activity and nutrition in schools by collaborating with diverse stakeholders in advocating, promoting, and implementing national and state initiatives.	<a href="http://www.ncactionforhealthykids.org/">http://www.ncactionforhealthykids.org/</a>
NC Healthy Schools	This program seeks to create a working infrastructure between education and health, to enable schools and communities to create a coordinated school health program.	<a href="http://www.nchealthyschools.org">http://www.nchealthyschools.org</a>
NC Physical Activity Policy Research Center	Since 2004, the center has studied the development, implementation, and effectiveness of policies related to increasing physical activity in communities.	<a href="http://prcstl.wustl.edu/research/Pages/PAPRN.aspx">http://prcstl.wustl.edu/research/Pages/PAPRN.aspx</a>
NC Planning Grant Initiative	An annual matching grant program supported by the NC Department of Transportation, to encourage municipalities to develop pedestrian and bicycle plans.	<a href="http://www.ncdot.org/bikeped/planning/">http://www.ncdot.org/bikeped/planning/</a>
NC Prevention Partners	A statewide nonprofit working to reduce preventable illness and early death caused by physical inactivity, poor nutrition, and tobacco use.	<a href="http://www.ncpreventionpartners.org">http://www.ncpreventionpartners.org</a>
NC Statewide Health Promotion Program	This program funds 85 local health departments and districts, to support community-based programs promoting policy and environmental changes that will support increased physical activity, healthy eating, and tobacco-use cessation.	<a href="http://www.ncpanbranch.com/SWHP.html">http://www.ncpanbranch.com/SWHP.html</a>
NC Safe Routes to School	This program enables community leaders, schools, and parents to improve safety and encourage more children to safely walk and bicycle to school.	<a href="http://www.saferoutesinfo.org">http://www.saferoutesinfo.org</a>

Note. All Web sites were accessed March 7, 2011.

that alternately help raise capital or address future land development.

Respondents reported that 26% and 31% of policies or regulations in local plans do not support walking and bicycling, respectively. For both walking and bicycling, the prevalence was much higher in rural municipalities than in urban municipalities. This may reflect conventional land use patterns and development policies in rural areas, which, since the mid-1900s, have emphasized low-density, auto-oriented growth and have not yet been updated with policies to support active living [39].

Some North Carolina communities integrate pedestrian and bicycle planning into local plans, such as transportation, land use, greenway, or park plans. Stand-alone pedestrian and bicycle plans are other avenues local governments can use to help create environments that support walking and biking. Such plans explain a community's vision and goals for future

activity; address relevant policies, programs, and facilities; and identify changes to laws and regulations that could enable residents to integrate walking and bicycling into daily routines. These plans also may set goals and benchmarks toward a more pedestrian- and bicycle-friendly community. In North Carolina, pedestrian and bicycle plans are less prevalent in rural areas than in urban areas and are less prevalent in places with smaller populations than in places with larger populations [25]. A majority of communities in North Carolina have neither type of plan [17]. In 2004, to encourage local entities to develop stand-alone pedestrian or bicycle plans, the North Carolina Department of Transportation's Division of Bicycle and Pedestrian Transportation and Transportation Planning Branch initiated a competitive grant program to encourage municipalities to develop pedestrian and bicycle plans [40]. The funding has continued yearly, helping municipalities develop or update pedestrian or bicycle plans.



**TABLE 5.**  
**Select Strategies and Tools That Can Impact Walking and Bicycling in Municipalities**

Strategy/tool	Description
Capital improvement program	A 5- to 6-year schedule of capital projects [29]. Capital planning involves the purchase or construction, major repair, reconstruction, or replacement of capital items, such as buildings, utility systems, roadways, bridges, parks, landfills, and heavy equipment.
Complete streets	A policy and related guidance on how to design streets to be safe for all users, including pedestrians, bicyclists, transit riders, motorists, and individuals of all ages and capabilities. The NC Department of Transportation Complete Streets Act of 2009 is part of a national movement that includes the federal Complete Streets Act of 2009. More information is available on NC ( <a href="http://www.nccompletestreets.org/policy.asp">http://www.nccompletestreets.org/policy.asp</a> ) and the United States ( <a href="http://www.completestreets.org/federal-policy/">http://www.completestreets.org/federal-policy/</a> ).
Concurrency requirements	An attempt to manage the timing of development so that it coincides with the availability of infrastructure capacity for community facilities, such as water, sewer, and transportation [30].
Crime Prevention Through Environmental Design	An evidence-based law enforcement strategy that attempts to build partnerships with residents and stimulate collective efficacy to solve problems [31]. It works through design and management of the physical environment of buildings, residential neighborhoods, and business areas, to increase public safety and reduce fear of crime. Additionally, community policing programs, by making police more visible and familiar to residents and with the physical environment of their beats, reinforce these efforts and promote police-citizen partnerships to prevent crime and disorder, which affects public health.
Health impact assessment	A set of procedures, methods, and tools by which a policy, program, or project may be judged for its potential effects on the health of a population and the distribution of those effects within the population [32].
Impact fees	Usually a single-time fee or charge on new development projects that is imposed by local government to cover capital expenditures on the infrastructure required to serve the new development [29]. In NC, impact fees are legal with prior General Assembly approval [33].
Joint-use agreement	A joint-use agreement is a formal agreement between 2 separate government entities that sets forth terms and conditions for shared use of public property or facilities ( <a href="http://www.nplanonline.org/nplan/joint-use">http://www.nplanonline.org/nplan/joint-use</a> ). An example is a joint-use agreement between a school and a city to use physical activity facilities.
Land trusts	A private nonprofit organization that has received a designation from the Internal Revenue Service as a 501(c)(3) corporation involved in charitable and educational activities [29]. It is common practice for land trusts to purchase open space and then to sell it to local and state governments for park land.
Mixed land uses	Mixed-use developments seek to create pedestrian-friendly environments, higher-density development, and a variety of uses that enable people to live, work, play, and shop in one place, which can become a destination [29].
Plans, such as pedestrian and bicycle plans	An adopted official statement of a local government that sets forth, in a public document, the community's vision and goals for future walking and bicycling. The plan may be called a comprehensive plan, general plan, or master plan [34, 35].
Public transportation	Transportation by bus, rail, or other conveyance, either publicly or privately owned, which provides to the public general or special service on a regular and continuing basis [36]. Also known as mass transportation, mass transit, and transit.
Safe Routes to School	A program that provides funding to enable and encourage children to walk and bicycle safely to and from school ( <a href="http://www.saferoutesinfo.org/">http://www.saferoutesinfo.org/</a> ).
Smart growth	Development that changes the terms of the development debate away from the traditional growth/no growth question to how and where new development should be accommodated. Principles include (1) mixed land uses, (2) taking advantage of compact building design, (3) creating a range of housing opportunities and choices, (4) creating walkable neighborhoods, (5) fostering distinctive and attractive communities with a strong sense of place, (6) preserving open space, farmland, natural beauty, and critical environmental areas, (7) strengthening and directing development toward existing communities, (8) providing a variety of transportation choices, (9) making development decisions predictable, fair, and cost-effective, and (10) encouraging community and stakeholder collaboration and development decisions [35].
Site design guidelines	A set of guidelines by a jurisdiction that must include provisions that address the needs of walkers, transit patrons, and bicyclists, especially in light of the Americans with Disabilities Acts and federal transportation legislation that supports multiple modes of transportation [29].
Subdivision ordinance	A regulation that controls the division of a tract of land for building and development purposes. It includes standards for the design and layout of lots, streets, utilities, and other public improvements, as well as procedures and requirements to ensure that public improvements are available when it is time to build on the lots [29].
Traffic calming	Using physical measures and barriers to deliberately reduce traffic speed and traffic volume, to make streets safer.
Transfer or purchase of development rights	The yielding of some or all of the right to develop or use another parcel of land or another portion of the same parcel of land more intensively [29]. When local governments or nonprofit organizations purchase development rights, the land stays in private ownership.
Transportation improvement program	A prioritized program or listing of transportation projects that is developed and formally adopted by a metropolitan planning organization as part of the metropolitan transportation planning process [37].
Universal design	Architectural planning designs that are intended to produce buildings and environments that are accessible to both able-bodied and disabled individuals [38]. Examples include sidewalk ramps and curb cuts.
Zoning ordinance	A legal document that describes each zoning district and the uses that may be allowed within the district [35].

Many North Carolina pedestrian and bicycle plans integrate health into their goals [34]. The degree to which the goals are met remains unknown. However, communities with plans that address walking and bicycling may have, over time, more infrastructure for walking and bicycling in the community that can, in turn, contribute to more physical activity and lower obesity rates. For example, in North Carolina, municipalities with local pedestrian plans had higher percentages of workers walking or bicycling to work than did areas without such plans [25]. Others have found that having a local pedestrian or bicycle plan increases the likelihood that walking and bicycling projects will be included in the TIP, which guides most state construction or reconstruction projects [41].

Health professionals and researchers alike can convey the possible health impacts of plans and policies, help institutionalize the role of health in ongoing planning, and ensure that health considerations are addressed in development decisions [27, 41, 42]. Additionally, with innovative approaches to the integration of primary care and preventive medicine included in the Affordable Care Act [43], primary care professionals could propose policy and environmental changes that promote better patient outcomes. Kingdon's framework on policy change [44], and examples of its implementation [45], lend support to this approach. Additionally, hospitals and health care facilities in several states are leading efforts to develop more supportive environments and policies for healthy lifestyles in their catchment areas. Regardless of the forum or role, a helpful initial step for health professionals may be to gain familiarity with relevant municipal, county, and state plans and policies, as well as their implementation processes.

Several respondents mentioned in the open-ended questions that state policies and practices could better support walking or bicycling in projects. Here, too, there is a role for health professionals. Those who communicate with state-level officials—be it on a committee, as part of a working group, or in some other way—have opportunities to convey many important health benefits associated with removing these barriers.

Our findings are subject to several limitations. First, respondent occupations varied across municipalities and included, for example, planners, planning directors, public works directors, and town managers. This reflects the diversity of job functions and positions across municipalities. In an effort to maintain consistency, the survey was targeted to the staff person most appropriate to talk about municipal pedestrian and bicycle planning. Second, some prevalence estimates had wide confidence intervals, as indicated by higher standard errors. The survey was weighted to represent all municipalities in the state of North Carolina. Nevertheless, these prevalence estimates should be interpreted in consideration of the precision of the estimates. Third, these data are subject to the potential of self-reporting bias. Fourth, we found some differences in municipalities

that responded to the survey, compared with municipalities that did not respond to the survey (Table 1). The strengths of the study included a statewide survey with estimates reflective of North Carolina municipalities on barriers to walking and bicycling projects and policies not previously explored in this way in the United States.

The present study offers a unique perspective of staff with the most knowledge about walking and bicycling, from a representative sample of North Carolina municipalities. The findings can help identify strategies for multidisciplinary partners, to address common barriers to walking and bicycling projects and policies reported by North Carolina municipalities. Health professionals, in particular, are well-positioned to take action by engaging with town officials, policymakers at all levels of governance, and community-based organizations, to support strategies that promote walking and bicycling in North Carolina. **NCMJ**

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## Acknowledgments

The content is solely the responsibility of the authors and does not necessarily represent the official views of the Robert Wood Johnson Foundation or the Centers for Disease Control and Prevention.

We thank Ginny Lee and Fang Wen for help with survey data collection and analysis.

Financial support. Robert Wood Johnson Foundation Active Living Research Program (grant 68511) and North Carolina Physical Activity Policy Research Center (Centers for Disease Control and Prevention cooperative agreement U48-DP000059), through the University of North Carolina Center for Health Promotion and Disease Prevention.

Potential conflicts of interest. All authors have no relevant conflicts of interest.

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# Suitability of Public Records for Evaluating Health Effects of Treated Sewage Sludge in North Carolina

Alexander Keil, Steven Wing, Amy Lowman

**BACKGROUND** Exposure to potentially harmful agents because of waste disposal practices is receiving increased attention. Treated sewage sludge (TSS), or biosolid material, is the solid waste generated during domestic sewage treatment after it has undergone processes to reduce the number of pathogens and vector attractants. Application of TSS to land, which is the most common method for disposal, is promoted as a soil amendment and fertilizer. Few studies have examined the effects of land application on the health and quality of life of neighboring populations. We describe and summarize publicly available records that could be used to study the public health impact of practices associated with land application in North Carolina.

**METHODS** We abstracted public records from the North Carolina Department of Natural Resources Division of Water Quality, to determine the following activities associated with land application of TSS in 8 counties in central North Carolina: the process for obtaining permits, reported applications, violations, documented concerns of residents, and penalties assessed.

**RESULTS** The Division of Water Quality routinely collects records of permits and approvals for land application of TSS, amounts applied, and reported pollutant levels. Documentation was useful in summarizing land application practices, but lack of standardization in reporting was a concern. Research into the public health impacts of the land application program is hindered by inconsistency in documenting inspections and resident concerns.

**LIMITATIONS** We were not able to validate state records with direct observation of land application of TSS.

**CONCLUSIONS** Records from the Division of Water Quality would be of limited use in epidemiologic studies of the health effects of land application of biosolids. Information about locations, amounts, and dates of application are relevant to exposure potential, but additional information is needed for health investigations.

**W**aste disposal practices may impact human health. In North Carolina, municipal, medical, industrial, and agricultural wastes are receiving increased attention because of health and environmental justice concerns [1-5]. While most solid and industrial wastes are disposed of in landfills, animal wastes and solids from municipal sewage (ie, sludge) are typically used as agricultural fertilizers, increasing their potential to affect the quality of air, water, and food. Animal manure and sewage sludge contain pathogens, endotoxins, allergens, and toxicants that have the potential to harm health and cause disease [6]. Studies of 16 eastern North Carolina communities located near industrial hog farms that apply swine waste to the land demonstrated human exposure to airborne pollutants [7] and dose-response relationships between pollutant levels, symptoms of illness, and stress levels in humans [8, 9]. Other research has demonstrated the presence of pathogens and antibiotic-resistant bacteria in surface waters near industrial swine farms [10].

Although municipal wastewater receives more treatment than animal waste, it includes chemicals from homes and industries that are not present in animal waste [11]. These chemicals and other constituents become concentrated in the residuals, or sewage sludge, resulting from wastewater treatment. After sewage sludge is processed to reduce

pathogens and vector attractants, the treated sewage sludge (TSS), also referred to as biosolid material [12], is commonly applied to farmland. Neighbors of fields where TSS is applied have reported respiratory, gastrointestinal, and irritation symptoms in response to the application [13-16], and 7 of 19 regulatory and health officials who were interviewed about their opinions on tracking and investigating health problems around sites of land application said they receive reports of illness from people living nearby [17].

The health impacts of swine waste [7-10], the presence of toxicants and pathogens in TSS [6], and national interest in tracking and investigating symptoms of illness in relation to sludge application [17] raise questions about the practice of applying TSS to fields in North Carolina. This article provides an evaluation of North Carolina's residuals management program and a summary of state records on the land application of sewage sludge in 8 North Carolina counties. The findings could help to increase awareness of medical

Electronically published May 20, 2011.

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and public health officials about the potential environmental health impacts of land-applied sewage sludge and could help state agencies initiate or participate in a program to track and investigate reports of illness.

## Materials and Methods

The North Carolina Department of Environment and Natural Resources Division of Water Quality (DWQ) oversees land application of sewage sludge in the state as part of its Residuals Management Program. We reviewed land application permits, annual reports, and electronic records of violations among permit recipients, recorded from 2005 through 2007, for 8 North Carolina counties near Chapel Hill, where this research was conducted.

**Permits.** To apply sewage sludge to land in North Carolina, appliers must obtain a Residuals Land Application Permit [18]. Permits contain information on the sources and destinations of sewage sludge. Source information lists generators (typically wastewater treatment plants [WWTP]), nutrients, hazardous wastes, and other pollutants measured in the sludge, and describes pathogen and vector attractant reduction procedures [18]. The permits note which fields are approved for application, but not the fields that are actually used. We abstracted information from an electronic database of active permits about the total number, locations, and acreage of associated fields. We abstracted dates and descriptions of permit violations and penalties from an electronic database of wastewater management events and reports of residents' concerns from paper copies of individual permits.

**Annual reports.** In North Carolina, permit holders are required to monitor levels of pollutants and indicator organisms in sewage sludge at least once per year and up to once per month, and they must submit an annual report to the DWQ that contains monitoring data, evidence of measures used to reduce pathogens and vectors, and other information [19]. We abstracted the dates of each application (ie, day, month, or bimonthly period); the amount applied in dry tons, gallons (for liquid sludge), and/or cubic yards (for cake

sludge; data were converted to gallons for comparisons); the crop grown on the sewage sludge amended fields; and the source WWTP(s). We abstracted this information from annual reports for municipalities with permits to apply sewage sludge in 8 counties in North Carolina.

For application amounts, we report the raw number of gallons of liquid sewage sludge applied to each field. We report application concentration in dry tons per acre and biosolid concentration in dry pounds per gallon. The term "dry weight" refers to the mass of the solid and dissolved constituents in the sludge.

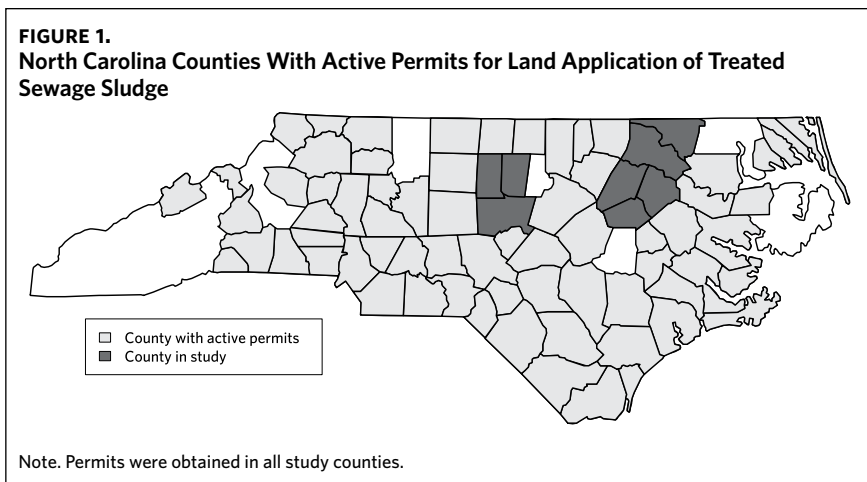
**Inspection documentation.** State inspections of land application sites are required when a municipality is undergoing the permit application or renewal process for a "site," defined as a field or group of fields in close proximity. Before application to land on a proposed site, DWQ officials review the plan for the proposed application and conduct a site visit to confirm that site operators are certified and that each field meets requirements for buffers and topographic characteristics. Inspectors use standardized inspection forms to document compliance or noncompliance with rules. We were unable to examine inspection forms systematically because of missing and/or checked out permits. We requested documentation of federal inspections, which occur biennially and assesses all points of sludge production and application, but no records were held by the DWQ.

We linked data from permits and annual reports to create summary statistics of sewage sludge application in 8 North Carolina counties from 2005 through 2007. DWQ personnel could not locate one of the annual reports for Orange County. We also assessed the consistency and completeness of records.

## Results

### Reported Land Application of TSS in North Carolina

As of July 2008, there were 148 active permits for land application of TSS on agricultural fields, with sites in 76 North Carolina counties (Figure 1). Of the 8 counties for which we abstracted annual report data, Alamance County had



the highest volume of applied sewage sludge (U53 million gallons), followed by Orange County ( $\geq 51$  million gallons), Chatham County ( $\geq 51$  million gallons), Edgecombe County ( $\geq 27$  million gallons), Nash County ( $\geq 22$  million gallons), Halifax County ( $\geq 9$  million gallons), Northampton County ( $\geq 6$  million gallons), and Wilson County ( $\geq 2$  million gallons) (Figure 1; Table 1). Agents who applied TSS in Wilson County reported the most concentrated sewage sludge (2.2 pounds dry weight per gallon), whereas agents in all other counties reported less than 1 pound per gallon. During 2005-2007, Orange County received sewage sludge from more WWTPs than any other county and had sewage sludge applied on 306 fields, which is nearly twice as many fields as Alamance County, the next most-active county of those we studied. The counties differed with respect to dry tons of sewage sludge applied per acre, ranging from 1.4 dry tons in Nash County to 7.2 dry tons in Wilson County. The maximum volume applied on any single field over span of the study period was nearly 6.5 million gallons, or 162 dry tons, which was applied to a 72-acre field in Chatham County.

During 2005-2007, the overall volume (in gallons) of sludge applied and the number of fields receiving application increased, while the dry weight or volume per acre did not change greatly within each county. The one exception was Wilson County, in which the dry tons per acre of application decreased from 10.7 dry tons in 2005 to 0.9 dry tons in 2007. Fescue was the most commonly reported crop to which sewage sludge was applied. Other crops were Bermuda and rye grass, corn, cotton, wheat, soybeans, and pine.

From 2005 through 2007, March, June, and November were the months in which the largest volume of sewage sludge was applied, although the pattern varied from year to year (Figure 2). A small proportion (<5%) of the residuals originated from water treatment plants, rather than from sewage treatment facilities (data not shown). Cumulative monthly application across all 8 counties was between 15 and 25 million gallons for all months except December and February.

### Completeness and Consistency of DWQ Records

**Annual reports.** Annual report forms generally included information on application locations and amounts of application for reported application events. There was inconsistency among permit recipients with regard to the reporting of application dates; some recipients listed the month (or bimonthly period) of application, whereas others reported specific dates.

**State inspection records.** At the state level, inspection forms (Figure 3) are filled out by DWQ employees, including a soil scientist, for routine inspections during the permit application or renewal process, for annual inspections, or after permit violations. Not all inspections occur during active application events. No inspection forms are retained with the permit if the inspection is performed when the process for obtaining the permit is being expedited, which requires an additional fee. We could not locate any record of the frequency of visits or inspections. DWQ personnel also conduct periodic, informal inspections of fields for some land application events, although these inspections are not systematically documented.

Known violations of state laws are recorded in an electronic database of more-general wastewater handling violations, such as sewage overflows. The recording of violation type is subjective. For example, a renewal form submitted after the deadline could be entered as "late renewal" or "permit conditions violation," depending on which DWQ personnel enter the data.

**Residents' concerns.** Residents are responsible for reporting concerns to appropriate authorities, and no centralized database of these reports exists in North Carolina. For example, if a resident contacts a health department to report concerns about land application, that report will not likely be recorded by state offices, and vice versa. Written concerns that are lodged directly with the DWQ are generally stored with the permit for which the concern has been stated, and e-mail correspondence is printed out and stored as a hard copy with the permit. Of note, one permit contained e-mails from several residents, including a physician, concerned

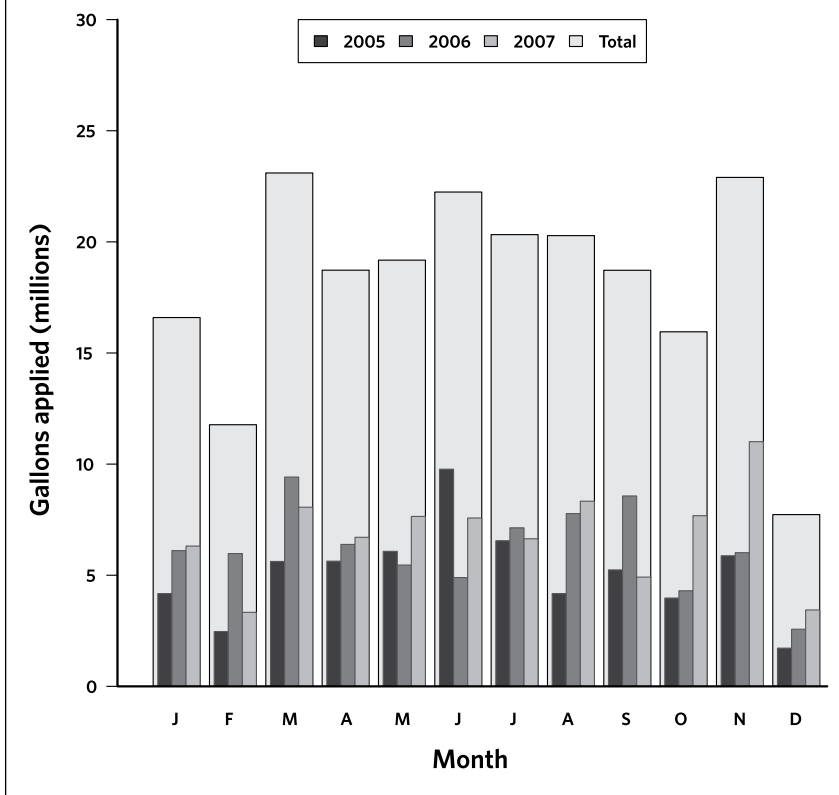
**TABLE 1.**  
**Sewage Sludge Application Summary for 8 North Carolina Counties**

Characteristic	Alamance	Chatham	Edgecombe	Halifax	Nash	Northampton	Orange <sup>a</sup>	Wilson
Permits, no.	3	8	4	4	2	3	5	1
Source WWTPs, no.	7	11	6	8	8	4	12	2
Fields used, no.	163	152	65	34	65	33	306	23
Volume, x10 <sup>6</sup> gallons	53.8	51.0	27.3	9.2	22.4	6.8	51.2	2.4
Dry mass								
Tons/acre	2.6	2.6	2.8	2.9	1.4	2.1	3.5	7.2
Pounds/gallon	0.3	0.3	0.4	0.4	0.2	0.4	0.6	2.2

Note. Data are from self-monitoring reports that must be submitted to the North Carolina Department of Natural Resources Division of Water Quality by applicators on an annual basis. WWTP, wastewater treatment plant.

<sup>a</sup>Records from 1 WWTP were missing for 2005.

**FIGURE 2.**  
**Gallons of Treated Sewage Sludge Applied Monthly in 8 North Carolina Counties**



about land application practices in Alamance County and physical symptoms exhibited by neighbors. No other reports of symptoms were found in the DWQ documents that we reviewed. The DWQ does not keep a summary of reported concerns or illnesses.

### Discussion

Evaluation of the safety of programs for applying TSS to land is generally based on risk assessments. These assessments neglect potential interactions between toxicants and pathogens in sewage sludge, which could make the assessments unreliable for predicting public health impacts [20, 21]. A review by the National Research Council [6] of epidemiologic studies relevant to the health of those living around sewage sludge application determined that only 23 studies addressed the connection between sewage sludge and human health. Only one of the studies evaluated residents living proximal to a site of application [22]. Authors of a survey in Ohio reported an excess prevalence of self-reported symptoms and illnesses within 1 mile of fields for which there were permits [23]. Given the many case reports of illnesses connected to land application of TSS [13-17], the dearth of observational studies is unfortunate; some authors have suggested that conflicts of interest have impeded in-depth investigation [24, 25].

To our knowledge, our research represents the first evaluation of DWQ records as a basis for quantifying amounts of

sludge applied to land, as well as associated time trends, seasonal patterns, and geographic variation. We have shown that, despite some weaknesses, the data are suitable for conducting basic surveillance of a practice that has the potential to affect the health of nearby populations. For example, during 2005-2007 more than 50 million gallons of sewage sludge was applied to 306 fields in Orange County. Since all of the TSS was applied via surface spreading, using equipment that broadcasts liquid or solid material, there is potential for drift, which could expose neighboring residents to toxicants, pathogens, and odorant compounds that could cause acute symptoms, reduce health-related quality of life, affect mental health, or contaminate ground or surface waters. To reduce the potential for pollutant drift into populated areas, surface application is illegal in North Carolina within 400 feet of a house; 50 feet of a property line; 100 feet of surface waters, wells, or swimming pools; and 25 feet of ephemeral streams [18]. However, pathogen repopulation in land-applied sewage sludge increases the potential for exposure to harmful constituents following land application [26].

We report both dry weight per acre, which relates to nutrient and pollutant load, and dry pounds per gallon, which relates to the concentration of waste in liquid applications. Since little is known about mechanisms by which sludge could cause symptoms, both are of potential interest for a public health investigation.

**FIGURE 3.**  
Sample Questions on a Form Completed During Inspection of Land Where Treated Sewage Sludge Has Been Applied

III. RENEWAL AND MODIFICATION APPLICATIONS (use previous section for new or major modification systems)

Description Of Waste(S) And Facilities

1. Are there appropriately certified ORCs for the facilities?  Yes or  No.  
Operator in Charge: [REDACTED] Certificate #: LA [REDACTED]  
Backup- Operator in Charge: [REDACTED] Certificate #: LA [REDACTED]

2. Is the design, maintenance and operation (e.g. adequate aeration, sludge wasting, sludge storage, effluent storage, etc) of the treatment facilities adequate for the type of waste and disposal system?  Yes or  No.  
If no, please explain: \_\_\_\_\_

3. Are the site conditions (soils, topography, depth to water table, etc) maintained appropriately and adequately assimilating the waste?  Yes or  No. If no, please explain: \_\_\_\_\_

Note. The form is from the North Carolina Department of Natural Researches Division of Water Quality.

Given our resources and the time and effort required to manually abstract data from paper copies, we were only able to evaluate records for a convenience sample of 8 counties from 2005 through 2007. Since the North Carolina residuals program is "a self-reporting program that requires permit holders to contact DWQ when permit violations occur" [19p15], there is room for improvement in tracking land application events that violate state and federal regulations [18, 27]. DWQ personnel may note violations they witness at inspections (eg, applying sewage sludge on a marked buffer) or violations of permit conditions (eg, submitting renewal forms after the deadline), but the inspection records held in the permits and database of violations are not detailed, systematic, or consistent enough to be research tools. On the day of our request, half of the nearly 15 permits we asked to examine for recorded violations were missing or checked out. One annual report was never located over the course of several months. We could not review documents for all counties in the state. However, if North Carolina's uniform reporting requirements are effective, records that we examined should be representative. Routine computerization of records would facilitate evaluation of time trends, spatial variation, and other surveillance. Since North Carolina follows federal minimum reporting requirements, records from other states should be at least as informative as North Carolina records; therefore, comparisons should be possible if these records can be centralized [27, 28].

One prior study of violations of land application regulations suggested that reporting patterns in other regions are similar to those in our investigation and found numerous examples of resident concerns that were not recorded by local agencies or were reported to the wrong agency [13]. Records may be limited because of the requirement for self-

report, and we could not evaluate medical documentation of reports. There is potential that the paucity of illness reports in our study results from nonsystematic recording of concerns by both local and state agencies.

Although DWQ records had limitations, including lack of direct observation of land application events and inconsistent reporting on the timing of applications, we believe these records constitute an important tool for public health investigation and exposure surveillance.

The second basic surveillance activity for evaluating the effects of land application of sludge on the health of North Carolina residents involves tracking reports of symptoms, illness, and diminished quality of life. Such information could be used to evaluate the locations of reports of health problems, secular trends, seasonal variation, associations with waste treatment methods, sources of waste, or sensitivity of neighboring populations (eg, children, elderly individuals, and people with allergies, asthma, or other sensitizing conditions). Health surveillance is a challenge because of a lack of awareness about sludge (including terms such as "biosolids" and "residuals," which may not be familiar to members of the public and health care professionals), variation in levels of concern about symptoms, and barriers to health care access, including lack of insurance coverage. Despite these difficulties, public officials connected with sewage sludge land application programs have an interest in conducting surveillance, which has been recommended by national and North Carolina officials [17, 21]. Federal regulations do not address criteria for keeping records of symptom reports, so the effort must come at state or local levels.

Health care professionals may not consider land-applied sludge as a possible source of illness because of their unfamiliarity with programs for disposal of wastewater residu-



als [13]. Increased awareness about possible health impacts of TSS among clinicians is important both for patient care and for epidemiologic investigation. For example, if sensitive patients present with respiratory symptoms in connection with land application of sewage sludge near their homes, they could be counseled to reduce or avoid exposure to outdoor air during those periods. Furthermore, clinicians could ask rural and semirural patients about possible exposures and could then contribute reports of symptoms to a health surveillance system. The Occupational and Environmental Epidemiology Branch of the North Carolina Department of Health and Human Services has previously recommended development of a surveillance program to track potential adverse health effects of land application of sewage sludge [21], and this scenario was one key component of a surveillance approach developed at the University of North Carolina–Chapel Hill, described in a report produced for the Water Environment Research Foundation [29]. The protocol is currently being tested in Ohio [30].

Impediments to performing basic research on the public health impact of land application of sewage sludge include lack of a health surveillance program and the dependence on groups that generate and apply sludge to report their own practices to a regulatory body that assesses violations and fines, which is an inherent conflict of interest. For example, one of us (A.K.) observed land application during a rain event, which is disallowed under state and federal laws and increases the likelihood of surface water contamination [18, 27]. More than 90% of the violations noted in DWQ records were a result of a paperwork error or a violation detected during inspection, hinting that violations may be unreported if they are not observed directly by the DWQ.

As the population of North Carolina increases, there will be more municipal sewage sludge and increasing pressure to apply TSS to land in rural and semirural areas that are experiencing population growth. Consequently, more residents may be exposed to the complex mixture of wastes and treatment byproducts present in TSS. Existing DWQ records can be useful to identify spatial and temporal variation in the potential exposure of North Carolina residents to land-applied sewage sludge, but an illness surveillance effort and a more systematic effort to report land application events in a consistent and complete manner would benefit future studies. Support from the medical and public health communities could help encourage better records and further the scientific understanding of potential health impacts of this growing program. NCMJ

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## Acknowledgments

Financial support. National Institute of Health Sciences (grants T32ES007018 and 5R01ES015469-04).

Potential conflicts of interest. All authors have no relevant conflicts of interest.

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# Quality of Pulmonary Function Testing in 3 Large Primary Care Pediatric Clinics in Rural North Carolina

Chris Gillette, Ceila E. Loughlin, Betsy Lynn Sleath, Dennis M. Williams, Stephanie D. Davis

**BACKGROUND** Pulmonary function testing (eg, spirometry) is recommended by the National Heart, Lung, and Blood Institute as part of basic asthma management. Previous research has shown that spirometry is feasible in primary care settings.

**OBJECTIVES** In this retrospective study, we sought to describe the proportion of spirometries meeting American Thoracic Society (ATS) and European Respiratory Society (ERS) quality criteria in children with asthma evaluated in North Carolina primary care pediatric clinics and to characterize predictors of spirometry that meets ATS/ERS quality criteria.

**METHODS** Medical records and spirometries from January 1, 2001, to August 1, 2009, were reviewed and analyzed from children enrolled in a larger asthma study that focused on communication between physicians, children, and caregivers. Children were eligible for the larger study if they were between the ages of 8 and 16 years and had received a previous diagnosis of persistent asthma. Children were enrolled from primary care pediatric practices.

**RESULTS** Spirometry was not acceptable, on the basis of ATS/ERS criteria, in 75% of cases. Approximately 19% of spirometries used incorrect or outdated predictive sets.

**CONCLUSIONS** More than three-quarters of spirometries in these primary care pediatric clinics were unacceptable. Changes or lack of changes in asthma management may be based on unacceptable spirometry. Additional education and training regarding accurate spirometry and interpretation are warranted.

Asthma currently affects approximately 9 million children in the United States and 7.9%-8.5% of children in North Carolina [1, 2]. The National Heart, Lung, and Blood Institute (NHLBI) recommends that all medical professionals who treat asthma patients have access to pulmonary function testing (eg, spirometry) [3]. Children as young as 4 years are able to complete spirometry in accordance with American Thoracic Society (ATS) and European Respiratory Society (ERS) guidelines, when trained and enthusiastic technicians perform the test [4]. However, very little is known about the quality of spirometry in primary care settings overall, and even less is known about spirometry quality in primary care pediatric clinics. Most children receive asthma care at generalist clinics, so it is important to assess the quality of spirometry in this setting [5].

Spirometry is a screening test of general respiratory health that provides important objective data to clinicians that assist diagnosis. The presence or absence of symptoms has not been shown to directly correlate with pulmonary function measures. The NHLBI recommends using multiple measures of asthma severity, such as symptoms, the need for short-acting beta-agonists, and spirometry results, in the initial diagnosis and subsequent management of asthma [3]. Spirometry that is technically incorrect may lead to substantial misclassification (due to false-positive or false-negative findings) of the child's pulmonary function and to unwarranted therapies or undertreatment.

There is evidence of a disparity in spirometry quality and

interpretation skills between office staff and hospital staff [6, 7]. There are also differences in performance between groups who have been trained intensively on spirometry and groups who have not been trained [7]. Nevertheless, the consensus from researchers and the NHLBI reflects agreement that spirometry in general practices is feasible if physicians and staff receive proper training [4].

The ATS and ERS have issued joint statements to reduce the variability in and improve the quality of spirometry. However, these guidelines may be too stringent for young children, and new acceptability criteria are now being proposed for this age group [8-12]. Table 1 highlights the criteria for performing spirometry on children, as defined by the ATS and ERS guidelines.

Additionally, there is published evidence that spirometry results affect treatment decisions and severity classifications for children who received abnormal spirometry results, but that investigation was performed in an outpatient pulmonary office [5]. To our knowledge, there are no data on the acceptability of spirometry results in a subspecialty clinic. However, given that respiratory therapists may receive

Electronically published May 20, 2011.

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**NC Med J.** 2011;72(2):105-110. ©2011 by the North Carolina Institute of Medicine and The Duke Endowment. All rights reserved. 0029-2559/2011/72203

**TABLE 1.**  
**Components of Acceptable Spirometry Among Children**

Component	Definition
Demographic variables	Correct height and weight must be obtained before spirometry
Predictive set	For children <8 years, use the set from Wang et al. [13]; for those aged ≥8 years, use the set from NHANES III [13]
Maximal exhalation duration	Children <13 years of age must exhale maximally for at least 3 seconds; those aged ≥13 years must exhale maximally for ≥6 seconds
Reproducibility	Values from the final 3 FVC and FEV <sub>1</sub> measurements must be within 10% of each other

Note. FEV<sub>1</sub>, forced expiratory volume in 1 second; FVC, forced vital capacity; NHANES, National Health and Nutrition Examination Survey.

more-intense training and clinic staff (ie, nurses) may have more experience conducting the test, spirometry performed in subspecialty clinics may differ in quality from spirometry performed in a primary care pediatric setting. Currently, there are certifications available from the National Institute for Occupational Safety and Health (NIOSH) on how to properly conduct spirometry [14, 15]. There are also certifications through Kettering National Seminars for individuals who wish to become registered pulmonary function technicians; these seminars are also accredited for continuing nursing education [15]. However, we are not aware of any studies that have evaluated this training and have examined the quality of spirometry in primary care pediatric settings. The ATS/ERS guidelines endorse that technicians in the United States should be certified through NIOSH, to ensure that they can correctly administer spirometry. The ATS/ERS guidelines also recommend that technicians undergo refresher training every 3-5 years, so they can learn new skills in spirometry [12].

To our knowledge, no studies have investigated the quality of spirometry in primary care pediatric clinics in North Carolina or other US states. There also has been no formal assessment of the impact of unacceptable spirometry on treatment decisions. Therefore, the aims of this study were to determine the proportion of spirometries that accorded with ATS/ERS guidelines (ie, "acceptable spirometry") among children evaluated in North Carolina primary care pediatric clinics and to characterize predictors of acceptable spirometry.

## Methods

**Participants.** This study was approved by the University of North Carolina-Chapel Hill Institutional Review Board, and the sample was drawn from a larger pediatric asthma study. In the larger study, children and their caregivers were recruited between 2006 and 2009 at rural primary care pediatric practices in North Carolina. Children were eligible for the larger study if they were 8-16 years of age, were able to speak English, could read the assent form, had been seen at the clinic at least once before, were present at the visit with an adult caregiver (parent or legal guardian) who could read and speak English and who was at least 18 years of age,

and were categorized as having mild or moderate/severe persistent asthma.

Subjects were eligible for the present study if at least 1 clinic visit before enrollment in the larger asthma study included spirometry. The subject's entire medical chart was required and was reviewed by C.M.G.

**Procedures.** We performed a retrospective analysis of spirometries and clinical characteristics of a subset of pediatric subjects currently participating in a larger asthma research study. For eligible children, medical records and spirometry data from January 1, 2001, to August 1, 2009, were reviewed and analyzed. Twenty-one pediatric medical providers and 100 of their subjects were enrolled into the present study. After initial analysis, we calculated the 25th and 75th percentiles of the dispersion of spirometries per subject, to determine subjects with an outlying number of spirometries. The number of spirometries per subject ranged from 1 to 7 (interquartile range, 1.75-5.25 spirometries/subject) during the study period. Three subjects underwent more than 5 spirometries and were classified as outliers and excluded from analysis.

After enrollment, data on all spirometries and patient clinical characteristics from each medical visit were abstracted from the medical charts. Each spirometry was then rated by a pediatric pulmonologist (C.E.L.) as acceptable or not acceptable, with stated reasons if not acceptable. Data from a random sample of 10% of the children were then analyzed by a second pediatric pulmonologist (S.D.D.), to verify concordance in the assessment of spirometry acceptability. Concordance between the 2 pediatric pulmonologists was 100%. Acceptability was based on ATS/ERS quality criteria [16].

**Measurement.** Age at each spirometry was measured as a continuous variable. Correct height and weight were measured as dichotomous variables. Child race was measured as white, African American, American Indian, Hispanic, or other. Asthma severity was classified as either mild persistent or moderate/severe persistent. Subjects were classified as having mild, persistent asthma if at least 1 asthma-control medication was being taken on the day of enrollment and/or asthma symptoms were experienced more than 2 times per week, but not every day, during the year before enrollment.

Subjects were classified as having moderate/severe persistent asthma if at least 2 controller medications were being taken on the day of enrollment and/or asthma symptoms were experienced on a daily basis during the year before enrollment [17]. Child sex was measured as a dichotomous variable.

The following variables were abstracted from the medical record for each clinical visit subjects had from January 1, 2001, to August 1, 2009: prescribed medication, defined as all medications to treat asthma (eg, short-acting beta-agonists and inhaled corticosteroids); frequency of use of all prescribed asthma medications (ie, controller and/or rescue inhaler/nebulizer) reported at the clinic visit at which spirometry was performed; performance of spirometry (at least 1 effort for a given test); height and weight, as noted on printed spirometry results; correctness of the predictive set, defined as the National Health and Nutrition Examination Survey (NHANES) III set [13], for children aged 8 years or older, and as the set by Wang and colleagues [13], for children younger than 8 years; presence of asthma symptoms on the day of the visit, as noted in the medical chart; and change in the prescribed asthma-control medication on the same day of the visit, defined dichotomously as “yes” or “no,” where “yes” was assigned if the physician (a) increased or decreased the dose for the current asthma medication and/or (b) added an asthma-control medication or had the child discontinue an asthma-control medication.

**Statistical analyses.** All analyses were conducted using SAS, version 9.2 (SAS Institute). First, a descriptive analysis of demographic variables and clinical characteristics was performed. Child race was recoded as a dichotomous variable (ie, “white” or “nonwhite”) for all analyses. Next, race and sex differences were analyzed for the total number of acceptable spirometries, as well as for the total number of spirometries, using independent sample *t* tests.

Zero-inflated Poisson regression was used to evaluate the relationship between the total number of acceptable spirometries and demographic variables (ie, asthma severity, race, and sex) [18]. There was also interest in evaluating the relationship between the number of excessive zeros in the outcome variable, the total number of acceptable spirometries, and the child’s age at the time of first spirometry. We hypothesized that age at first spirometry would be significant in the model because children who are older at their first spirometry would have fewer problems following the specific instructions that are required for technically acceptable spirometry. If we did not account for the excess of zeros in our outcome variable by using zero-inflated Poisson regression, it would have led to biased parameter estimates and incorrect inferences [19].

Multivariate logistic regression was used to examine the relationship between each spirometry and demographic variables (ie, asthma severity, race, sex, and age). We used Spearman’s rank correlation coefficient to determine whether there was a bivariate relationship between

the number of spirometries and acceptable spirometry for the sample. Finally, multiple logistic regression was used to examine whether a physician’s change to the child’s asthma-control medication was associated with subject age, asthma severity, presence of asthma symptoms, and acceptable spirometry (for the first 2 visits).

## Results

Table 2 shows the demographic characteristics of our sample. One hundred subjects were enrolled, and 97 were included for analysis. We analyzed 196 spirometries for the 97 subjects. The mean age ( $\pm$ SD) of subjects at first spirometry was  $10.6 \pm 2.3$  years, with a range of 5 to 15 years. All subjects had received a previous diagnosis of asthma and met NHLBI guidelines for diagnosis. Seventy-two percent of children were classified as having moderate/severe persistent asthma by a clinical pharmacist with experience in asthma (D.M.W.) and by a pediatric pulmonologist (S.D.D.). The mean number of spirometries ( $\pm$ SD) per child was  $2.0 \pm 1.1$ . There were no statistically significant differences between races and sexes in the total number of spirometries. Additionally, there were no significant demographic differences in the total number of acceptable spirometries (data not shown).

In total, 50 (25%) of spirometries were acceptable on the basis of ATS/ERS criteria. Figure 1 shows the most-prevalent reasons why spirometry was not acceptable. Each category is not mutually exclusive. The most prevalent reasons for unacceptable spirometry were reproducibility and nonmaximal efforts. Spearman’s rank correlation coefficient suggested that the relationship between the number of spirometries and the total number of acceptable spirometries was not statistically significant ( $\rho = 0.17$ ;  $P = .09$ ).

**TABLE 2.**  
Demographic Characteristics of Study Participants

Characteristic	Subjects, no. (%) (N = 97)
Sex	
Male	55 (56.7)
Female	42 (43.3)
Race	
White	58 (59.8)
Black	29 (29.9)
Hispanic <sup>a</sup>	3 (3.1)
Other <sup>b</sup>	7 (7.2)
Asthma severity <sup>c</sup>	
Mild, persistent	26 (26.8)
Moderate/severe persistent	70 (72.2)
No data	1 (1.0)

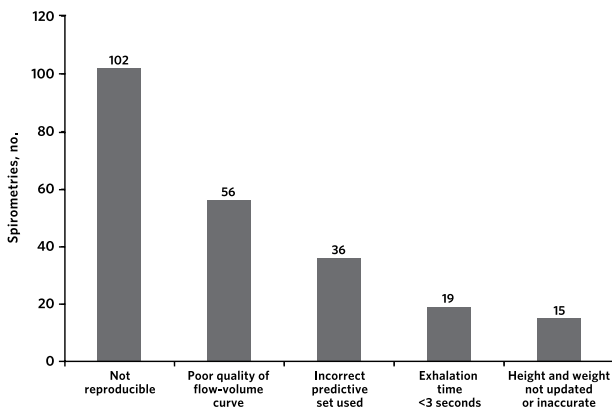
Note. The mean age ( $\pm$ standard deviation) at first spirometry was  $10.6 \pm 2.3$  years, with a range of 5 to 15 years.

<sup>a</sup>Includes Mexican Americans.

<sup>b</sup>Includes subjects with mixed race.

<sup>c</sup>See Methods for definitions of asthma severity.

**FIGURE 1.**  
Reasons for Unacceptability of Spirometry



Note. Data are for 147 spirometries considered to be unacceptable on the basis of American Thoracic Society and European Respiratory Society guidelines. Individual spirometries can appear in >1 category.

The zero-inflated Poisson regression results showed no significant associations between the total number of acceptable spirometries and demographic variables (data not shown). Multiple logistic regression results showed no significant predictors of acceptable spirometry, after control for each individual spirometry (data not shown). Thirty-eight spirometries (19%) were done using outdated or incorrect predictive sets, with the first session having the greatest concentration of outdated or incorrect predictive sets (almost 31%).

Asthma-control medication was changed in association with 22 unacceptable spirometries (15%), with no clinical symptoms documented in the medical chart to explain the change. Conversely, asthma-control medication was not changed in association with 48 unacceptable spirometries (33%), with clinical symptoms noted in the medical chart that may have prompted a change in medication otherwise. Multiple logistic regression analysis showed no statistically significant associations between changes to prescribed asthma medications and either demographic variables or clinical aspects of the visit, such as the presence of asthma symptoms (data not shown).

## Discussion

Our results show that the quality of spirometry for children in these primary care pediatric clinics was poor, with only 1 in 4 tests being acceptable, as defined by ATS/ERS guidelines. The most common problems with spirometry among these patients were reproducibility and submaximal efforts. For our study, a child was included even if only 1 spirometric maneuver had been attempted. Therefore, it is likely that issues with reproducibility could be even greater than what this study reports. This has important treatment implications because exhalations that are not performed maximally by the patient can lead to important misclas-

sifications that may result in suboptimal or unnecessary therapies.

The technical quality of spirometry is extremely important for validity and reproducibility. Failure to meet the quality standards for 1 component of the test can influence the interpretation of the results. For example, an exhalation that is not done at maximal inspiratory capacity may not detect an obstructive component. Failure to obtain 3 measurements with values that are within 10% of each other suggests poor reproducibility of FEV<sub>1</sub> (forced expiratory volume in 1 second) results. An inadequate duration of measurement can also affect the results. The FVC (forced vital capacity) is dependent on an adequate measurement period. If the duration of measurement is too short, the FVC will be underestimated, which affects the FEV<sub>1</sub>/FVC ratio. Technicians who conduct spirometry on children should be trained thoroughly so that they can help young patients attain maximal effort, which is crucial to the correct interpretation of spirometry results. The courses taught by NIOSH should be able to help technicians obtain the best efforts from children.

There were no statistically significant predictors of acceptable spirometry in our data set. This is extremely important because one hypothesis is that the prevalence of acceptable spirometries is greater among children who have undergone more spirometries. However, this association was not detected in our study. Although we did not analyze the association between individual technicians and the prevalence of acceptable spirometries, past research has shown that proper training of both physicians and nurses results in high-quality spirometry [5]. We chose not to analyze individual technicians because the technician's name was not updated in the computer each time spirometry was attempted. This makes it impossible to tell which technician was actually performing the spirometry.

Physicians changed decisions about medication management in association with approximately 15% of unacceptable spirometries, with no asthma symptoms documented in the medical chart to explain the change. Previous studies have found that spirometry results prompt pediatric pulmonologists to change medication, but further research would need to replicate the study by Nair and colleagues [5] in primary care pediatric offices, to determine the role of spirometry in medication-management decisions made by general pediatricians.

We also found that providers did not change asthma medication in association with almost 33% of unacceptable spirometries, even though the medical chart documented that the child was experiencing asthma symptoms at the visit. It is important to note that the spirometers used in these cases had interpretive software, which may by itself have influenced management decisions. There were no instances in which the spirometer's interpretive software acknowledged poor spirometry quality.

Almost one-fifth of all spirometry was performed using outdated or incorrect predictive sets. One explanation for

this finding could be that technicians in general pediatric clinics may lack important knowledge to properly select correct reference values. Another explanation for the finding could be that the spirometers used at these clinics were outdated and lacked the ability to download updates. This further points to a need for more-thorough training and education of technicians.

Accurate clinician interpretation of pulmonary function is dependent on correct performance of spirometry. However, correct performance was rare in our sample. There were instances in which technicians did not update the height and weight of patients for more than 2 months (some data had not been updated for more than 1 year), as well as instances in which the wrong age was entered into the computer (the age of one child was entered as 88 years, instead of 9 years). If a technician inputs the wrong demographic parameters, such as height and age, for a subject, then output variables, such as FVC and FEV<sub>1</sub>, are also incorrect. Therefore, if a subject has an obstructive component in their breathing, the condition might not be detected because the variables for predicting pulmonary function are incorrect. In a case in which height was not updated for more than 1 year, the physician clearly wrote in the medical chart that spirometry results were normal. The physician then decreased the dose of asthma medication, even though the patient was experiencing symptoms that suggested that spirometry results were incorrect. Physicians rely on technicians to perform the test correctly, and good patient outcomes depend on correct test interpretations.

Spirometers are often purchased from companies that provide limited training to clinic office staff. One solution to this issue is that companies that provide spirometry equipment should provide continuing education and training on spirometry. For practices that have already purchased spirometry equipment, it is important that their technicians receive certification to conduct the test. No staff in this study were respiratory therapists, and none had a certification through Kettering or NIOSH, which, if received, could lead to improvements in quality at these clinics. The staff that received training when the spirometer was originally purchased may no longer be working at the clinic, or there may be new staff who never received proper training. It might also be more feasible for practices to have consistent personnel who are trained in acceptable spirometry and/or to have 1 trained physician dedicated to interpreting spirometry results.

Future research needs to focus on the training of clinic personnel who perform spirometry, as well as on analyzing the quality of spirometry before and after training, to determine the effect of training. It will be important to determine whether individual technicians have an effect on the ability to perform acceptable spirometry on a child. Additional studies are also needed to analyze the importance that physicians place on spirometry results in treatment decisions.

Our research should be considered in light of the limita-

tions of our study. First, we did not have direct access to each medical encounter at which spirometry was performed, and therefore we cannot directly conclude that spirometry results had a direct impact on disease management. For example, the physician may not have noted symptoms in the medical chart, but symptoms may have been discussed, leading to a change in treatment. Another limitation is that we did not directly compare individual technicians and cannot conclude that technicians are the most important factor in determining acceptable spirometry. We could not assess how many individuals have performed spirometry at each site, because of turnover of clinic staff over a 9-year period. Our subjects were not tested on the same day in a pulmonary function laboratory or by a trained technician, and therefore we cannot rule out that our population had characteristics that prevented them from undergoing acceptable and reproducible spirometry. Furthermore, since our inclusion criteria allowed children into the study who had performed only 1 spirometric maneuver instead of 3, reproducibility issues in our sample could have been even worse. Last, our data are limited to rural North Carolina and may not be generalizable to other geographic areas.

In conclusion, only 25% of spirometries in these primary care pediatric clinics were acceptable. Given that most asthmatic children receive asthma care from generalists and that spirometry is recommended as basic asthma management in national guidelines, it is not ideal that spirometry is restricted to tertiary care centers and subspecialty providers. Changes or lack of changes to the management of asthma medication may be based on results from a technically unacceptable spirometry. Further training and education is necessary to justify the continued use of the test in primary care pediatric clinics. **NCMJ**

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#### Acknowledgments

Financial support. National Heart, Lung, and Blood Institute (grant HL069837).

Potential conflicts of interest. All authors have no relevant conflicts of interest.

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# Improving Asthma Care in Emergency Departments: Results of a Multihospital Collaborative Quality Initiative in Rural Western North Carolina

*Steven Crane, Douglas Sailer, Steven C. Patch*

**BACKGROUND** In North Carolina, nearly one-fourth of persons with asthma visit an emergency department (ED) or urgent care center at least once a year because of an exacerbation of asthma symptoms. The Emergency Department Asthma Program was a quality-improvement initiative designed to better understand the population of patients who use the ED for asthma care in rural western North Carolina and to demonstrate whether EDs at small hospitals could, by implementing National Asthma Education and Prevention Program treatment guidelines, improve asthma care and reduce subsequent asthma-related ED visits.

**METHODS** Eight hospitals in western North Carolina participated in the project, which lasted from November 2003 through December 2007. The intervention consisted of a series of individual and structured continuing medical education events directed at ED physicians and staff. Additionally, patients presenting to EDs for asthma-related problems were selected to receive a short patient questionnaire, to determine their basic understanding of asthma and barriers to asthma care; to undergo asthma staging by the treating physician; to receive focused bedside asthma education by a respiratory therapist; and, finally, at the treating physician's discretion, to receive a free packet of asthma medications, including rescue therapy with a beta-agonist and corticosteroid therapy delivered via a metered-dose inhaler, before discharge.

**RESULTS** During the 37-month project, a total of 1,739 patients presented to the participating EDs for 2,481 asthma-related episodes of care; at 11% of these visits, patients received the intervention, with nearly 100 ED physicians referring patients to the program. Most of the patients using the ED for asthma treatment were judged to have the mildest stages, and nearly half were uninsured or were covered by Medicaid. For only 20% of the visits was a primary care physician or practice identified. The patient intervention did not appear to lessen the rate of return visits for asthma-related symptoms at 30 and 60 days.

**LIMITATIONS** Selection bias is likely, as patients enrolled in the study were more likely than patients in the target sample to be adults and insured. Because we did not measure ED staff attendance at educational sessions or their knowledge of and attitudes about asthma care before and after the educational program, we cannot draw conclusions about the effectiveness of the program to change their knowledge, attitudes, or behavior.

**CONCLUSIONS** Many patients who use the ED for care appear to have mild, intermittent asthma and do not identify a regular source of primary care. Efforts to improve asthma care on a communitywide basis and to reduce preventable exacerbations should include care provided in EDs, as this may be the only source of asthma care for many asthma patients. The project demonstrated that regional, collaborative performance improvement efforts in EDs are possible but that many barriers exist to this approach.

**M**ore than 22 million Americans have asthma, including an estimated 6 million children. The burden of asthma affects patients, their families, and society in terms of lost workdays and school attendance, decreased quality of life, and avoidable emergency department (ED) visits, hospitalizations, and deaths [1]. The prevalence of childhood asthma in North Carolina is greater than the national average. Although asthma is a chronic condition with effective preventive treatments available, nearly 25% of adults and children with asthma visit an ED or urgent care center at least once per year because of an asthma-related illness, with two-thirds of these individuals making 3 or more visits during the year [2].

For a number of years, primary care professionals have been encouraged to improve asthma staging and education and to provide asthma action plans to patients, to reduce the number of preventable asthma exacerbations leading to

an ED visit [2]. Community Care of North Carolina (CCNC) has included asthma care as part of its regular quality audits for primary care practices participating in the Medicaid program [3].

Many asthma patients appear to use the ED as their usual source of health care, in part because of a number of perceived and real barriers to primary care access in a community. Low income, difficulty making or keeping an appointment, and the perception that an ED visit has lower out-of-pocket expenses than an office visit all appear to con-

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Electronically published May 3, 2011.

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**N C Med J. 2011;72(2):111-117.** ©2011 by the North Carolina Institute of Medicine and The Duke Endowment. All rights reserved. 0029-2559/2011/72220

tribute to use of the ED for routine asthma care [4]. Among children with asthma, lower rates of continuity with primary care professionals are associated with higher risks of ED use [5]. If substantial numbers of asthma patients bypass primary care altogether, then attempts to improve asthma care in the community and to reduce preventable ED visits should include input from EDs.

Asthma care in EDs may differ substantially from National Institutes of Health guidelines, with considerable variation by type of hospital [6]. We observed in our hospital that patients were rarely discharged with a prescription for asthma controller medication, such as an inhaled corticosteroid (ICS), and that asthma staging and education about recognition and treatment of early symptoms were not routinely part of the ED treatment protocol.

Performance improvement programs instituted in a single ED have been shown to produce sustained improvement in asthma care [7]. Providing asthma medication at discharge and reminding patients to follow up with a primary care professional increase the likelihood that patients will reestablish contact with a primary care professional for additional asthma education [8]. During a pilot performance improvement project, we observed that many patients who presented to the ED appeared not to have a primary care professional and had mild forms of asthma, with rare or infrequent exacerbations. If this observation is true in other communities, the ED may be the sole source of asthma care for many patients in our region. We further observed that ED staff were amenable to changing treatment protocols if they were provided with data suggesting that changes might reduce subsequent ED visits. If the EDs in a region could work collaboratively to implement guidelines-based asthma care in their departments, it might be possible to achieve substantial improvements in care for a population of asthma patients previously not served by programs aimed at improving asthma care in primary care practices.

With support from The Duke Endowment and the

Western North Carolina Health Network (WNCHN), we conducted a multihospital, collaborative quality-improvement initiative to create a standardized clinical pathway for ED-based asthma care that adhered more closely to National Asthma Education and Prevention Program (NAEPP) guidelines. We sought to improve our knowledge of the patients in the region who use the ED for asthma care, including their understanding of asthma control and barriers to care. Because a previous pilot project determined that many patients either left the ED without a prescription for an ICS metered-dose inhaler (MDI) or failed to fill the prescription after leaving, the intervention included issuance of controller medications to patients at discharge to see whether this would reduce subsequent asthma-related ED visits.

## Methods

The Emergency Department Asthma Program (EDAP) was a collaborative quality-improvement project conducted by the WNCHN, a consortium of 16 hospitals in western North Carolina, as part of a larger initiative funded by The Duke Endowment to improve asthma care. Three of the 16 hospitals in the WNCHN agreed to participate in the pilot project that began in November 2003, with 5 additional hospitals enrolled over the subsequent months. All of the hospitals were small or moderate sized not-for-profit facilities that serve largely rural communities in western North Carolina (Table 1). Each participating hospital's chief executive officer and ED medical director provided administrative approval and signed a business associate agreement to allow performance data to be collected, analyzed, and shared by the collaborating hospitals and the WNCHN. There were no financial incentives provided to the hospitals to participate, other than in-kind educational programs, patient-education materials, and sample medications that EDs could distribute to patients as part of the EDAP discharge packet. A participating hospital's institutional review board reviewed the proposal and deemed this a quality-improvement initiative

**TABLE 1.**  
Collaborative Site Size and Enrollment of Asthma Patients During Emergency Department (ED) Visits

Site	Beds, no.	Staff type	Asthma-related visits, no.	Visits involving enrollment, no. (%)	ED physicians with >1 enrollment, no.
Hospital A	59	Contract	47	1 (2)	1
Hospital B	26	HE	29	28 (97)	2
Hospital C	222	Contract	948	121 (13)	40
Hospital D	65	HE	428	9 (2)	7
Hospital E	103	HE	46	45 (98)	21
Hospital F	85	HE	159	0	0
Hospital G	94	Contract	266	44 (17)	17
Hospital H	86	HE	558	25 (4)	10
Overall	740	...	2,481	273 (11)	98

Note. HE, hospital employee.

limited to promoting the implementation of a national treatment and staging guideline study and, therefore, exempt from guidelines addressing human experimentation.

Each participating hospital selected a project team that consisted of an ED physician champion, a respiratory therapist, an ED nurse, and representatives from the medical records department and administration. The EDAP coordinating team included the project coordinator, a primary care physician, and pulmonary and allergy specialists, who assisted in developing an evidence-based ED clinical pathway for asthma patients on the basis of NAEPP guidelines for asthma staging and treatment; the clinical pathway at each hospital was reviewed and adopted by the hospital's project team. Standardized patient questionnaires, educational materials, staging forms, and asthma medication packets were prepared by the coordinating team and distributed to each participating ED (Appendix, available only in the online edition of the NCMJ). Staging questions included whether the patient used more than 1 MDI canister per month, whether they had nightly symptoms, or whether their asthma routinely affected daily activities such as work or school. Patients' self-management skills were assessed by asking whether they had an asthma rescue plan and whether they possessed and used a peak-flow meter at home. Finally, we assessed barriers to outpatient asthma care by asking patients whether they had a primary care professional and whether they had difficulty paying for their asthma medications.

The project sponsored a well-attended kickoff continuing medical education event directed at ED physicians and featured a nationally recognized ED physician champion for improving asthma in the ED setting. The coordinating team provided continuing in-service educational sessions on the care guidelines at each hospital, by means of academic detailing by asthma specialists who practiced in those communities; sessions were attended by more than 100 regional ED physicians. The coordinating team also provided short educational updates at departmental meetings for respiratory therapists and registered nurses at each participating hospital. The project coordinator made regular visits to each hospital during the study period, provided personal reminders to staff about the hospital's asthma care guidelines, and prominently posted a number of visual reminders in staff work areas in the participating EDs. Enrollment numbers for each hospital were provided to project teams at least quarterly, and modest enrollment incentives were provided to respiratory therapists at various times during the initiative, to encourage regular use of the pathway. Staff knowledge and attitudes about asthma were not specifically measured before and after the educational program, as champions at each hospital felt that such a survey would be off-putting to staff. But the project coordinator solicited feedback from nursing, RT, and physician staff at each regular visit, to assess perceptions of the impact of the program on ED asthma care at each hospital during the study period.

All patients aged 4 years or older who presented to the ED with an asthma-related diagnosis (determined on the basis of *International Classification of Diseases, Ninth Revision* [ICD-9] diagnosis codes), regardless of payer source, were eligible for enrollment. The clinical pathway included 5 steps, and documentation for each step was contained on 1 sheet attached to the patient's ED medical record.

For step 1, if the triage nurse believed the patient's chief complaint was asthma related, an asthma assessment sheet was attached to the chart. The triage nurse filled out the patient's basic demographic information; asthma-related history, including current asthma medication; whether the patient used a spacer; and whether the patient had a current primary care and/or pulmonary or asthma specialist.

For step 2, if the evaluating ED physician agreed that the primary presenting problem was asthma related, the physician completed a simple asthma staging form on the basis of NAEPP clinical staging criteria. The patient then received usual asthma care, as deemed appropriate by the treating physician.

For step 3, the respiratory therapist assigned to administer nebulizer treatments to the patient recorded the patient's pretreatment and posttreatment peak flows; administered a short survey on asthma knowledge and barriers to asthma care; and provided a short, focused, and structured educational intervention that emphasized use of the short-acting "rescue inhaler" versus the long-acting "controller," the importance of recognizing asthma "triggers," and the need for an asthma action plan to improve asthma self-care.

For step 4, when the patient's health had improved sufficiently to be discharged from the ED, the physician was encouraged to dispense an asthma medication "prepack," if deemed appropriate. This contained an albuterol MDI, a steroid inhaler, written instructions about proper MDI use, and a brochure describing local resources for outpatient care. The prepacks were dispensed to all patients, regardless of payer status.

For step 5, the completed asthma assessment sheet was placed in a box and collected weekly by project staff, for data entry and analysis. Sample data collection forms and educational materials are available in the Appendix.

Data were collected from participating hospitals as they joined the project, which lasted from November 2003 through December 2007. Data from the asthma assessment sheets were collected and entered in an Access 2007 database (Microsoft). Additional information, about each patient's other hospital visits, as well as payer source and charge information, was obtained from each hospital's medical records system. ED visits coded as asthma-related visits by use of the ICD-9 codes were included in the database as the denominator. The records were then deidentified of any unique patient identifiers and aggregated. No patient-specific information was shared with any other facility. Data were reported back to each hospital on at least a quarterly basis during the period in which they participated in the

project. At the end of the project, each hospital was provided with a copy of the database containing only their data, as well as with instructions about how to continue using the software to track their asthma care performance.

Demographic characteristics of enrolled patients were compared with those who did not enroll, by use of a 2-sided likelihood ratio  $\chi^2$  test. Revisit occurrences were compared using the Fisher exact test. Use of a 2-sided test revealed that a sample size of 82 in each group would be required to have a 90% chance of finding a statistically significant difference in the revisit rate between the 2 groups, if one group had a 10% revisit rate and the other had a 30% revisit rate. SAS, version 9.1.3 (SAS Institute), was used to calculate P values, and the threshold for statistical significance was defined as a P value of <.05.

## Results

All 8 of the participating hospitals contributed their data on asthma-related ED visits, and 7 of the hospitals enrolled at least 1 patient into the intervention. During the 37-month project, 1,739 patients presented to participating EDs, for a total of 2,481 asthma-related visits. Characteristics of the participating hospitals and asthma-related ED visits and the proportion of patient visits in which the patient was enrolled into the intervention are summarized in Table 1.

More than half of the visits for asthma among enrolled patients involved individuals who either were covered by Medicaid or had no insurance. Only 273 (11%) of the total visits by asthma patients were by patients enrolled in the intervention. The enrolled population was less likely to include children and more likely to include insured patients (Table 2). Additionally, for 1,988 (80%) of the 2,481 ED-related asthma visits, either the patient or the ED staff did not acknowledge that the patient had a primary care physician.

The surveys returned by patients regarding asthma stage, the control of their asthma symptoms, and the bar-

riers to this care varied from hospital to hospital. The most common asthma stage diagnosed during visits by enrolled patients (117 [43%] of 273) was mild, intermittent (Table 3). Even though the enrolled population from which these survey data were derived was more likely to have private insurance, nearly 50% of participants reported difficulty affording their asthma medication, a finding that appeared across the region (Table 4). Finally, whether the patient was enrolled in the intervention did not appear to affect the rate of return asthma-related visits at 30 or 60 days (Table 5).

## Discussion

The EDAP was designed to provide information associated with the following questions: (1) What are the characteristics of the asthma patients using the ED in the region? (2) Could quality improvement across hospitals in a region be successful? (3) Could providing a basic bedside asthma education in the ED and providing patients with controller medications at discharge reduce subsequent visits to the ED for asthma care?

The project appeared to support our earlier observations that most patients using the ED for asthma care had intermittent or rare symptoms and did not identify a source of routine primary care. The majority of patients had the mildest stages of asthma, which should be the stages that are most amenable to prevention or self management. Even though our enrolled sample of visits were more likely to include insured patients, we found that 80% of visits were from patients who did not identify a primary care professional. Only one-third of patients identified an asthma rescue plan other than visiting the ED, and only 13% reported having a peak-flow meter, which would form the basis of a self-management plan. More than one-quarter of patients reported poorly controlled symptoms, gauging by the number of quick-action MDIs they used in 1 month, the presence of nocturnal symptoms, or asthma symptom-related limita-

**TABLE 2.**  
Characteristics of Asthma-Related Visits to the Emergency Department, by Patient Enrollment Status

Characteristic	Enrolled, no. (%)	Not enrolled, no. (%)	Likelihood ratio	P
Age, years			19.9	<.001
4-19	49 (18)	574 (26)		
20-46	167 (61)	1,038 (47)		
>46	57 (21)	596 (27)		
Sex		0.38	.54	
Male	109 (40)	839 (38)		
Female	164 (60)	1,369 (62)		
Insurance status			45.8	<.001
Medicaid/Medicare	22 (8)	508 (23)		
Commercial	213 (78)	1,325 (60)		
Uninsured	38 (14)	375 (17)		

**TABLE 3.**  
**Asthma Stages Diagnosed Among Enrolled Patients During the Emergency Department Visit**

Asthma stage	Patients, no. (%)
Mild intermittent	117 (43)
Mild persistent	29 (11)
Moderate persistent	62 (23)
Severe	22 (8)
Not staged	43 (16)
Total	273 (101)

Note. Because of rounding, percentages do not sum to 100.

tions to their daily activities. Affordable asthma medications were an important barrier to care, reported by nearly 50% of patients. Approximately three-fourths of such patients were younger than 46 years, and 50% were either uninsured or covered by Medicaid. These are not surprising findings, given that asthma tends to be a disease of younger patients and that younger patients (particularly children) are less likely to have insurance and are more likely to be covered by Medicaid. The survey data suggest that barriers to care and no regular primary care professional are region-wide problems among asthma patients in western North Carolina, even though the communities served varied widely with respect to primary care options available to those without insurance.

Although many of these patients, perhaps, do access a primary care professional for other medical problems, the fact that one was not recorded prevented the primary care professional from being notified of the ED visit and prevented the ED from arranging an appropriate follow-up plan

for the patient. We did not ask whether patients first tried contacting their primary care professionals before visiting the ED or whether an outpatient visit occurred between the first and the subsequent ED visit, which occurred within 60 days for 7% of patients. Although both factors could represent additional barriers to early asthma care, neither change our key finding that a substantial number of patients in our sample appear not to use primary care as a source of care for their asthma exacerbation. This would bolster our contention that asthma care in the ED should include elements of prevention and of recognition and management of early symptoms, if we expect to have a major impact on reducing preventable asthma ED visits.

With respect to collaborative quality-improvement efforts in the ED, EDAP was the first such effort in our region. Although it was a relatively simple intervention and focused on 1 disease, because of the way hospitals are structured it turned out to be a rather complicated project, involving more than 100 ED physicians, as well as the administration, ED nurses, respiratory therapists, and finance and information technology departments at each of the 8 hospitals. Although each hospital had official buy-in from the chief executive officer and physician champion, there was a wide variation in enrollment rates, from 0% to 98%, between the hospitals (Table 1). Most of the participating hospitals demonstrated a willingness and an ability to adopt an evidence-based clinical pathway for asthma care; however, almost none were able to maintain a level of consistent performance, despite frequent reminders. Anecdotally, we encountered a number of barriers to getting changes to “stick” in the ED. These included turnover of physician, nurse, and respiratory therapist champions at the participating hospitals; competing quality initiatives in the various departments; and a frequently voiced attitude among ED staff that it was their role

**TABLE 4.**  
**Barriers Reported by Enrolled Patients to Controlling Asthma Symptoms Before the Emergency Department Visit**

Site	Barrier, no. (%) of enrolled patients						
	Patients enrolled, no.	Use of >1 MDI per month	No rescue-therapy plan	No peak-flow meter at home	Nightly symptoms	Adverse affects on daily activity	Difficulty affording medication
Hospital A	1	1 (100)	0	1 (100)	0	0	0
Hospital B	28	7 (25)	10 (36)	4 (14)	15 (54)	13 (46)	5 (18)
Hospital C	121	30 (25)	61 (50)	17 (14)	77 (64)	57 (47)	53 (44)
Hospital D	9	5 (56)	3 (33)	1 (11)	2 (22)	1 (11)	5 (56)
Hospital E	45	13 (29)	5 (11)	5 (11)	0	0	24 (53)
Hospital F	0	0	0	0	0	0	0
Hospital G	44	7 (16)	3 (7)	3 (7)	2 (5)	3 (7)	20 (45)
Hospital H	25	3 (12)	5 (20)	5 (20)	3 (12)	3 (12)	12 (48)
Overall	273	66 (24)	87 (32)	36 (13)	99 (36)	77 (28)	119 (44)

Note. MDI, metered-dose inhaler.

**TABLE 5.**  
**Rates of Hospital Revisitation for**  
**Asthma Treatment at 30 and 60 Days,**  
**by Enrollment Status**

Interval	Patients, no. (%)		P <sup>a</sup>
	Enrolled	Not enrolled	
30 days	13 (4.8)	103 (4.7)	.88
60 days	19 (7.0)	148 (6.7)	.7

<sup>a</sup>By the Fisher exact test.

was to treat the presenting symptoms and that primary care professionals were responsible for providing education on prevention and self-management.

Nevertheless, the project demonstrated that quality-improvement collaboration across hospitals in a region can be an efficient means to develop evidence-based clinical pathways, patient-education materials, and programs for educating primary care professionals. Sharing processes and tools across a network can reduce the cost of quality-improvement efforts, which may be particularly important for small hospitals, which typically have fewer resources to expend in these areas. Even some staff from hospitals that enrolled few, if any, patients in the program believed the regular reminders yielded increased awareness of NAEP guidelines among ED staff and that more patients left the ED with prescriptions for steroid inhalers as a result of the intervention. The observation that more than 100 different ED physicians in the region enrolled at least 1 asthma patient during the intervention suggests that a substantial number of ED physicians had received at least a portion of the education, resulting in performance of at least 2 recommended asthma care steps (ie, staging the patient's asthma episode and providing the patient with controller MDIs at discharge from the ED).

The patient intervention did not appear to decrease the rate of return visits for asthma-related symptoms at 30 and 60 days. Although, given the relatively small number of patients enrolled in the intervention and the small number of patients returning because of symptoms within 60 days, this study was not sufficiently powered to detect anything other than a large difference. Furthermore, if the educational intervention changed the behavior of some physicians, as was reported to us anecdotally, and if it resulted in more steroid-inhaler prescriptions written for patients not enrolled in the program, the difference in return visits between the 2 groups would be reduced. On the basis of extensive documentation in the literature that controller medications for persistent asthma reduce exacerbations, we would expect that any intervention that increased the use of these medications by asthma patients would ultimately reduce ED visits.

Finally, our experience with EDAP not only underscores the need for coordination across the continuum of care in a community, it also highlights how difficult that is to achieve in our fragmented health system. Follow-up from ED care to

primary care is a key step, but it is missing in most asthma care provided in the ED, and primary care appears to need improvement in providing asthma patients with better self-management strategies and tools. Because many asthma patients may not fully recognize that their symptoms are poorly controlled, we need community strategies that aim to inform the public about how to control asthma symptoms, reduce preventable use of the ED, and decrease job or school absences due to asthma exacerbations. But until there are better incentives to provide coordination at every step of the care process, these efforts will be difficult to initiate and maintain.

Emerging use of electronic medical records in EDs may present a method to implement system-wide care changes in the ED that incorporate more evidence-based care choices, such as those attempted in EDAP, and would facilitate monitoring the effectiveness of interventions to improve care. Given that our experience demonstrated that 25% of all asthma-related ED visits were by patients covered by Medicaid, CCNC networks could use real-time data on ED visits for enrolled patients to better identify which patients might benefit from additional asthma self-management trainings and tools.

EDAP was undertaken as a voluntary, regional, collaborative performance improvement project in EDs. Enrollment of patients in the intervention was not random, but at the discretion of the ED staff, so caution should be used in applying the results of the barrier and staging surveys to the entire population. Because our sample had more insured patients, one would expect that the barriers to affordable asthma medication and the prevalence of no regular primary care professional would be worse for the overall population of asthma patients who use the ED for treatment of symptom exacerbation. If confirmed, this finding would substantiate the importance of increasing the number of ICS prescriptions by ED physicians as a community intervention to reduce the frequency of acute exacerbations in this population. A further limitation is that these are observational data, and patients enrolled in the intervention may differ significantly from those not enrolled. Because we could not collect detailed prognostic factors from the unenrolled group, we are not able to adjust or control for these factors. We have concluded that there was not a significant difference in the asthma revisit rates between the enrolled and the unenrolled patients, but it is possible that there may have been differences, stratified by asthma stage, between the groups had we been able to perform a subgroup analysis.

EDAP did not collect formal data on educational outcomes for the various ED staff affected by the intervention, in accordance with customary standards for in-service education at each participating hospital. There is no reason to expect, though, that the continuing medical education kickoff event for physicians, the professional detailing, or the regular reminders and handouts at departmental meetings were any less effective than usual means to educate pri-

mary care staff about guideline-based care. And given the frequent reminders, the methods in this project were more likely to be effective than usual methods. Anecdotal reports appeared to support the impression that knowledge and awareness of NAEPP treatment guidelines among ED staff increased as a result of the project. Further studies would be helpful to specifically measure which method is the most effective in improving knowledge and changing behavior.

EDAP was the first multihospital, collaborative clinical-improvement project attempted in our region. Although no significant reduction in the number of ED revisits resulted from this collaborative intervention, this project proved that collaborative interventions can be implemented in this region. Valuable asthma-related data were captured, which can be used in further studies and to provide effective primary asthma care. Although the project focused on asthma care provided in the ED, our findings suggest that continued efforts are needed to improve communication with primary care professionals and referral back to primary care settings, where much of this care should be provided. NCMJ

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#### Acknowledgments

Potential conflicts of interest. All authors have no conflicts of interest.

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**“WHEN I HAVE AN  
ASTHMA ATTACK  
I FEEL LIKE A FISH  
WITH NO WATER.”**

**—JESSE, AGE 5**



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# POLICY FORUM

## *Public Health and Environmental Health*

### Introduction

The policy forum of this issue of the NCMJ draws from the papers and discussions of the 2010 Environmental Health Summit, held in Research Triangle Park, North Carolina, last fall. The theme of that summit is the theme of this issue: bringing public health and environmental health together. Public health and environmental health have not always been so apart. The text of *On Airs, Waters, and Places*, from the Hippocratic Corpus, offered this advice to people who would seek to understand medicine:

Whoever wishes to investigate medicine properly, should proceed thus: in the first place to consider the seasons of the year... We must also consider the qualities of the waters, for as they differ from one another in taste and weight, so also do they differ much in their qualities. In the same manner, when one comes into a city to which he is a stranger, he ought to consider its situation, how it lies as to the winds and the rising of the sun... These things one ought to consider most attentively, and concerning the waters which the inhabitants use, whether they be marshy and soft, or hard, and running from elevated and rocky situations, and then if saltish and unfit for cooking; and the ground, whether it be naked and deficient in water, or wooded and well watered, and whether it lies in a hollow, confined situation, or is elevated and cold; and the mode in which the inhabitants live, and what are their pursuits, whether they are fond of drinking and eating to excess, and given to indolence, or are fond of exercise and labor, and not given to excess in eating and drinking.

This advice was and remains sound, but we have let our understanding of how and where we live, in the environmental sense, drift away from how we study, care for, and improve the health of people and populations. The environment in which we live is a strong determinant of how well we will live. We also have influence over that environment, and we ought to consider how we modify it in the sense of those who wish to “investigate medicine properly” for people and populations. In this issue, we see how we can better understand how what we do to live shapes where we live and, in turn, makes our lives better or worse.

The process of better understanding these connections has been improved by technologies such as geographic information systems and structured assessment methods. But there still remains a strong political element in the calculus of how we are to manage where and how we live. That calculus puts some people at greater risk because of the effects of our social and economic choices. Knowing that does not always mean that we can fix it. We still have to struggle to balance the needs of society with the demands that a healthy environment will bring.

Mankind can adapt to many “insults,” as René Dubos wrote, but that adaptation is not always passive. We must learn to shape how we live, as well as where we live, to make for a healthy planet and livable communities.

*Thomas C. Ricketts III, PhD, MPH  
Editor in Chief*



# Reducing North Carolina's Health Care Costs Through Environmental Disease Prevention

Jacqueline MacDonald Gibson, Leah Devlin, David Brown, Martin Armes

At a time of unprecedented pressure on the North Carolina state budget, reducing environmental risks to health may provide opportunities for substantial savings in the proportion of the state budget (24%) that is allocated for medical assistance. Recently, the Research Triangle Environmental Health Collaborative held a summit to identify options for increasing attention to environmental impacts on health in the ongoing health care and budget debates. Summit participants included not only public health and environmental experts, but also individuals (such as transportation planners, developers, and industry representatives) whose decisions can have a significant impact on environmental quality. This article summarizes key recommendations from the summit, as well as commentaries in the policy forum of this issue that further elaborate on why environmental quality matters for public health in North Carolina. Key recommendations from the summit include requiring formal health impact assessments (similar to environmental impact assessments but with an emphasis on health) in state and local transportation and land use planning processes, quantifying the total disease burden attributable to environmental hazards in North Carolina, prioritizing environmental risks to health in North Carolina, providing state technical assistance for communities disproportionately affected by poor environmental quality, establishing a new database system to link existing environmental and public health data by geographic location, undertaking North Carolina case studies to test the hypothesis that improving environmental quality also reduces medical care costs, and developing "environment matters to your health" public awareness campaigns.

*Whoever wishes to investigate medicine properly, should proceed thus: in the first place to consider the seasons of the year. . . . Then the winds . . . , especially such as are common to all countries, and then such as are peculiar to each locality. We must also consider the qualities of the waters, for as they differ from one another in taste and weight, so also do they differ much in their qualities.*

Hippocrates (attributed), *On Airs, Waters, and Places*

As this quotation from the Hippocratic Corpus illustrates, the belief that environmental factors are associated with preventable diseases is a long-established concept in public health. Although the past century has witnessed dramatic improvements in public health because of environmental interventions such as improved water and sanitation systems, environmental risks remain important contributors to public health problems. The World Health Organization estimates that, all told, environmental risk factors are associated with approximately 17% of the total disease burden in industrialized nations [1].

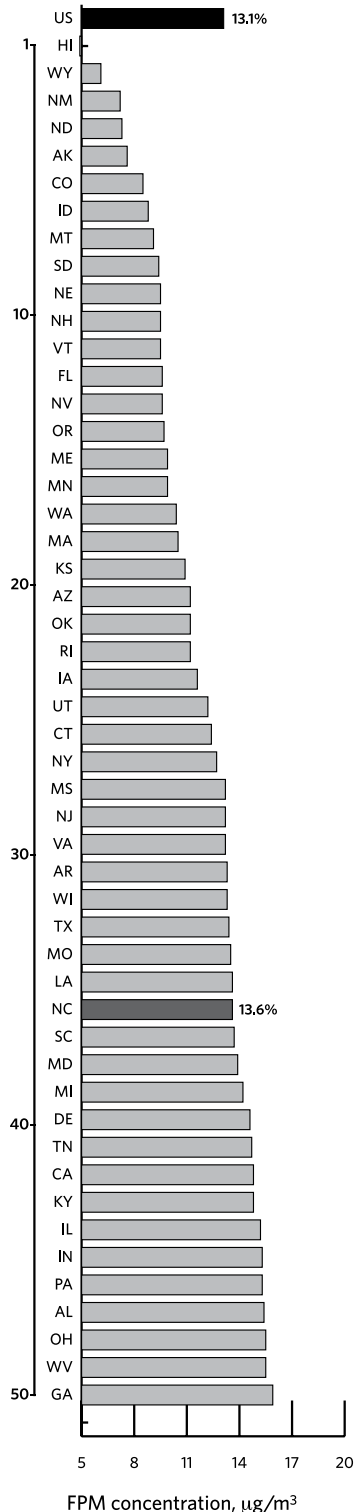
US states have not undertaken comprehensive assessments of the burden of environmental disease, so comparing North Carolina's status with that of other states on this important public health measure is not possible. However, for the limited environmental factors for which assessments have been undertaken, North Carolina scores relatively poorly. For example, North Carolina has the 15th highest concentration of fine particulate matter in air among US states, according to the North Carolina Institute of Medicine Task Force on Prevention (Figure 1) [2]. High levels of particulate matter in outdoor air contribute to high rates of respiratory and cardiovascular diseases. In North Carolina, fine particulate matter in air is a causative factor in 6,000 hospital admissions for respiratory distress and 3,000 premature deaths each year, the latter of which accounts for 3%-7% of all deaths not due to violence or unintentional injury [3]. While environmental exposures are just one cause of preventable diseases and premature deaths, North Carolina compares relatively poorly with other states in terms of indicators of disease and death. According to the United Health Foundation [2], North Carolina ranks 36th among states in overall population health (with 1 being the best) and 38th in terms of premature mortality.

Electronically published May 20, 2011.

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**NC Med J. 2011;72(2):119-124.** ©2011 by the North Carolina Institute of Medicine and The Duke Endowment. All rights reserved. 0029-2559/2011/72206

**FIGURE 1.**  
**Average Concentration of Fine Particulate Matter (FPM) in Air During 2005-2007, Nationally and by State**



Note. Data are from [2]. FPM is defined as particles with a diameter of  $\leq 2.5 \mu\text{m}$ . Numerals in the y-axis denote state rank.

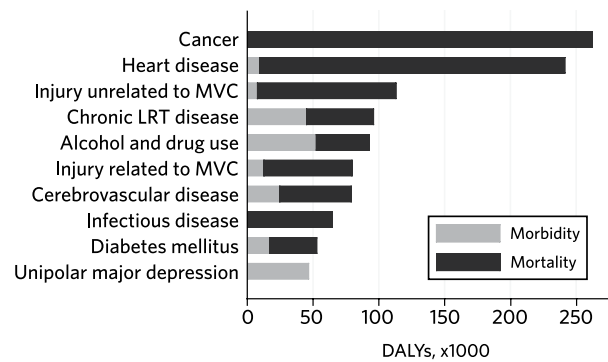
An increased burden of environmental disease translates to significant economic implications for medical care systems. Landrigan and colleagues [4] estimated that 4 environmentally mediated chronic health conditions in children (ie, lead poisoning, asthma, cancer, and neurobehavioral disorders) cost the nation \$54.9 billion per year. Several individual states have completed similar assessments on children, with state-specific total annual medical care costs for select diseases ranging from \$1.57 billion to \$5.8 billion [5-8]. North Carolina researchers have estimated that the burden of just 1 health outcome category (ie, respiratory disease) and 1 type of pollution (ie, particulate matter in outdoor air) costs the state medical system nearly \$14 million annually [3].

At a time of unprecedented pressure on the state budget, North Carolina can ill afford to continue paying for preventable disease associated with environmental factors. In fact, medical assistance programs accounted for 24% (\$10.4 billion) of the state's total budget of \$42.8 billion in 2009-2010 [9]. Given that 3 of the 4 leading causes of death and illness in North Carolina—cancer, heart disease, and chronic lower respiratory disease—are initiated or exacerbated by environmental risk factors (Figure 2), improving the environment offers substantial opportunities for North Carolina to save money through environmental initiatives that prevent disease [2]. Yet, the potential for increased environmental protection to yield health care savings for North Carolinians has received scant, if any, attention in ongoing debates over both the state budget and health care reform. In fact, the North Carolina legislature is proposing cuts of 22% in the budget for the Department of Environment and Natural Resources (DENR), the state agency chiefly responsible for ensuring environmental protection [10, 11].

The commentaries in the policy forum of this issue focus on research and practice to understand and reduce environmental impacts on the public's health in North Carolina and elsewhere. As the commentaries illustrate, North Carolina has pioneered new research methods, policies, and community engagement strategies focused on understanding and preventing environmentally mediated diseases. Actions in all of these areas—scientific research, policy improvements, and community engagement—will be necessary to reduce the state's burden of preventable disease. Such an effort by North Carolina can then serve as a model for improving similar conditions in other states across the nation.

With these considerations in mind, the Research Triangle Environmental Health Collaborative (available at: <http://environmentalhealthcollaborative.org/about/overview/>) recently held a summit to identify ways to increase attention to environmental impacts on health in the ongoing health care and budget debates. One goal of the summit was to bring together individuals and organizations not traditionally associated with public health or environmental health but whose decisions can have a significant impact on health outcomes. Participants included land use and transportation

**FIGURE 2.**  
**Top 10 Causes of Morbidity and Mortality in North Carolina,**  
**as Measured by Disability-Adjusted Life Years (DALYs)**



Note. Data are from [2]. Three of the 4 leading causes (ie, cancer, heart disease, and chronic lower respiratory tract [LRT] disease) can be triggered or exacerbated by environmental pollution. MVC, motor-vehicle crash.

planners, housing developers, architects, agricultural industry representatives, and federal, state and local government personnel. This diverse array of summit participants divided into 3 subgroups and then convened in plenary sessions to develop 3 types of recommendations: policies, to prevent or reduce environmental impacts on the disease burden and the medical care system; research and analytical tools, to support existing and new policies to prevent and reduce environmental impacts on health and the medical care system; and opportunities for public outreach, education, and mobilization, to reduce the impact of environmental quality on human health and the medical care system.

This article summarizes innovative projects pertinent to each of these 3 topics in North Carolina, as described in more detail in the policy forum of this issue. It also highlights some of the key recommendations from the North Carolina Environmental Health Summit. A complete list of the presentations and recommendations is posted on the Research Triangle Environmental Health Collaborative Web site (available at: <http://environmentalhealthcollaborative.org/summit/presentations1/>).

## Policies

The commentary by Ross [12], former secretary of the North Carolina Department of Environment and Natural Resources, describes North Carolina's leadership in reducing air pollutant emissions from coal-fired power plants, which has resulted in measurable improvements to air quality. A 10-year collaborative research project, the Southern Appalachians Mountains Initiative, demonstrated that North Carolina would gain substantial benefits from reducing emissions of nitrogen oxides and sulfur dioxides from the state's coal power plants. According to Ross, this research led to consensus that these emissions indeed had measurable public health impacts and therefore needed to be reduced. Subsequent negotiations between the state legis-

lature and the electric utility industry led to a new law, the Clean Smokestacks Act of 2002, that reduced air pollution and, by allowing accelerated tax write-offs for pollution controls, was financially feasible for the utility industry. Ross shows the significant decreases in air pollution levels that have resulted from this legislation, which went beyond federal mandates for power plant emissions reductions.

While the Clean Smokestacks Act represents clear North Carolina leadership in policies to reduce environmental risks to public health, many problems remain. Participants in the Environmental Health Summit emphasized the particular need for policies to reduce health disparities that result from differences in environmental toxicant exposures. The commentary in this issue by Wilson [13], president of the West End Revitalization Association (WERA; Mebane, NC), emphasizes the disproportionate exposure to environmental hazards faced by the state's minority and low-income communities. In North Carolina's low-income communities, these hazards include lack of access to basic water and sanitation services (ie, public water supplies and sewerage services) that are now taken for granted in the state's middle- and high-income communities.

Summit participants recommended as a possible policy change a new requirement to include formal health impact assessments, similar to environmental impact assessments, in state and local transportation and land use planning processes. Current federal law (ie, the National Environmental Policy Act of 1969) requires environmental impact assessments for any project that involves federal funding or permits. These environmental impact assessments focus mainly on ecosystems. Although health impact assessment is widely practiced in other parts of the world, currently the United States does not require health impact assessments for new projects. North Carolina could provide leadership in advancing health impact assessment as an evidence-based tool for supporting public policy decisions. Such assessments also could increase attention on how new projects (such as new highways or industrial facilities) affect the health of existing communities—including low-income and minority communities—and how alternative designs could decrease these impacts.

Summit participants also suggested that North Carolina policymakers initiate formal planning exercises at the county and state levels to select environmental health priorities and identify interventions that will improve the health of the largest number of people and the communities most severely affected. Community input and participation in the selection of priorities and interventions could be required. To structure the planning processes, counties and the state could consider using the methods described in the policy forum by MacDonald Gibson [14] for combining systematic community engagement with quantitative environmental burden of disease assessment by public health experts. North Carolina counties conduct community health assessments (which include limited environmental risk informa-

tion) every 4 years. Stronger, more targeted environmental health assessments could be incorporated in these ongoing community health assessments.

While requiring health impact assessments for new projects and county-level environmental health assessments are top-down approaches to focusing attention on the linkages between environmental quality and public health, Environmental Health Summit participants also emphasized the need for political support of bottom-up approaches that are focused on education and technical assistance for communities. Participants recommended a state commitment to provide technical assistance to communities facing disproportionate environmental disease burdens.

## Research and Analytical Tools

The commentaries in this issue's policy forum highlight exciting new opportunities for research to improve understanding of the complex links between environment and health, to support evidence-based policy making.

Olden and colleagues [15] write about the potential for new research tools in genetics to shed light on the interplay between environmental and genetic factors in disease initiation and progression. Olden is former director of the National Institute of Environmental Health Sciences, the nation's premier federal environmental health research agency, located in Research Triangle Park, North Carolina. Olden and colleagues recommend developing a database of epigenetic markers (ie, observed changes in human cellular factors other than DNA sequence that affect cellular function) gathered in parallel with environmental and genetic information from populations in different neighborhoods. Such a database could serve as a platform for transdisciplinary research to understand the complex gene-environment interactions thought to be major factors in the etiology of diseases that contribute disproportionately to the nation's health care costs.

Miranda and Edwards [16], researchers at Duke University's Nicholas School of the Environment, provide several examples of how new geographic information system (GIS) and statistical tools have already been used in North Carolina to improve understanding of the links between environmental risk factors and public health. As examples, GIS tools have been used to identify homes most at risk for lead contamination and to target blood lead screening to those at-risk neighborhoods, using the maps as powerful tools to communicate risks to the affected communities. Similarly, GIS tools have been used to inform policies concerning arsenic testing of private wells, which provide drinking water for more than 2 million North Carolinians. North Carolina's universities have developed some of the most powerful tools, now used worldwide, for such geospatial analysis [17].

Summit participants stressed the potential for research on a variety of fronts to provide a stronger information base to support policy making. Participants recommended that North Carolina researchers pursue a variety of case studies that could test the hypothesis that improving environmen-

tal quality also reduces medical care costs. For example, researchers could compare health status in counties that have different environmental risk factors. Similarly, public health researchers could analyze health data before and after legislation (such as smoking bans or reductions in permissible air emissions) to improve environmental quality.

An additional recommendation was to conduct case studies in North Carolina to quantify the local and regional burden of disease due to different environmental factors and to estimate the medical care cost savings that might accrue with decreased exposures to environmental risk factors. For some environmental risk factors, such as exposure to air and water pollution, data are already routinely collected, and relevant health and health care expenditure data can be gathered from existing sources, including various data sets available from the North Carolina Center for Health Statistics, making such efforts possible at relatively low cost.

Summit participants also recommended that North Carolina pursue a number of activities to restructure existing data, to facilitate research on the connections between environment and health. For example, one recommendation was to develop the spatial architectures needed to integrate existing data on environmental exposures, health, and pollutant concentrations. The new database technologies should be able to combine spatially resolved environmental data with health records at the individual and population levels, while protecting the privacy of personal health data. Such data structures would facilitate low-cost research to understand linkages between environmental exposures and health.

## Community Outreach

While disparities in exposure to environmental risk factors remain pervasive in North Carolina, the state also has produced examples of successful, community-based, collaborative decision making on development projects with potential environmental and health impacts.

Wilson [13] describes WERA's work to engage community members, local university science experts, and government agencies to identify and reduce environmental hazards in low-income communities. The Environmental Protection Agency recently named WERA as a prototype model for engaging communities in reducing the local health effects of environmental hazards associated with transportation corridors.

Contrary to a commonly held belief that environmental protection is detrimental to economic development, improved environmental stewardship can benefit not only community health but also local economic development, contends Levine [18], professor in the Department of Epidemiology and Public Health at North Carolina State University, in the policy forum. Levine presents several examples of cooperation among businesses, local community members, state agencies, and environmental groups to craft plans that enable strong local economic development

**TABLE 1.**  
**Select Resources in North Carolina for Addressing Environmental Risks to Health**

Affiliation type, organization	Web site	Major activities
<b>University</b>		
Dept of Environmental Sciences and Engineering, GSGPH, UNC-CH	<a href="http://www.sph.unc.edu/envr/">http://www.sph.unc.edu/envr/</a>	Conducts interdisciplinary research and teaching of the effects of environmental contaminants on human health and the effects of human activity on the environment
UNC-Chapel Hill Dept of Epidemiology, GSGPH, UNC-CH	<a href="http://www.sph.unc.edu/epid/">http://www.sph.unc.edu/epid/</a>	Conducts research and teaching to understand the patterns and causes (environmental and other) of health and disease
Institute for the Environment, UNC-CH	<a href="http://www.ie.unc.edu/">http://www.ie.unc.edu/</a>	Coordinates environmental research and outreach across departments and centers of UNC
Nicholas School of the Environment and Earth Sciences, DU	<a href="http://www.nicholas.duke.edu/">http://www.nicholas.duke.edu/</a>	Conducts research and outreach on environmental issues
Dept of Civil, Construction, and Environmental Engineering, NCSU	<a href="http://www.ce.ncsu.edu/">http://www.ce.ncsu.edu/</a>	Conducts research on new technology for emerging environmental problems
<b>State</b>		
Dept of Environment and Natural Resources	<a href="http://portal.ncdenr.org/web/guest">http://portal.ncdenr.org/web/guest</a>	Administers programs to protect air quality, water quality, and public health
Div of Public Health, Dept of Health and Human Services	<a href="http://publichealth.nc.gov/">http://publichealth.nc.gov/</a>	Administers disease prevention, health services, and health promotion programs in collaboration with local health departments, hospitals, community health centers, practitioners, and community agencies
<b>Federal</b>		
National Institute of Environmental Health Sciences	<a href="http://www.niehs.nih.gov/">http://www.niehs.nih.gov/</a>	Supports research to understand how the environment influences the development and progression of human disease
Environmental Protection Agency	<a href="http://www.epa.gov/rtp/">http://www.epa.gov/rtp/</a>	RTP campus is the primary center for air pollution research and regulation; also houses National Health and Environmental Effects Research Laboratory, National Center for Computational Toxicology, and other research centers focused on environmental impacts on health
<b>Other</b>		
NC Environmental Health Collaborative	<a href="http://www.EnvironmentalHealthCollaborative.org">http://www.EnvironmentalHealthCollaborative.org</a>	Connects organizations; links research and policy; and joins government, academia, industry, and public interest groups to mutually consider, discuss, and debate the future of environmental health on a regional, national, and international level
RTI International	<a href="http://www.rti.org/">http://www.rti.org/</a>	Provides government and private-sector clients with environmental and public health expertise
The Hamner Institutes for Health Sciences	<a href="http://www.thehamner.org">http://www.thehamner.org</a>	Fosters translational research in environmental health sciences and chemical risk assessment

Note. Dept, department; Div, division; DU, Duke University; GSGPH, Gillings School of Global Public Health; NCSU, North Carolina State University; RTP, Research Triangle Park; UNC-CH, University of North Carolina-Chapel Hill.

and environmental protection. As an example, he cites a committee of developers, builders, community members, and environmental groups that conceived of a plan to allow major new residential developments in Wake County, North Carolina, while also meeting requirements for the protection of Falls Lake. The committee devised local ordinances that specified landscape design features to minimize surface water runoff to the lake by dispersing rainwater over natural areas, to support infiltration and evapotranspiration.

The need for community engagement in local decisions that affect environmental quality and, thus, public health was one of the most prevalent themes at the Environmental Health Summit. The participants' primary recommendation was to enlist marketing experts to develop "Environment Matters to Your Health" campaigns, using North Carolina as a test case and local foundations to provide funding. The

campaigns would be designed to educate and mobilize the public around pertinent environmental health issues. When an environmental health issue of concern is identified, each affected community includes individuals with different views of the problem. Some people care passionately about the potential health impacts of environmental exposures, possibly because they have been directly affected; others are indifferent or uninformed; and others oppose action to protect the environment. In addition, some community members have more political influence than others. Messages need to be tailored differently, to target groups with different viewpoints and levels of influence. The marketing campaigns would target 4 different audiences, with a separate messaging strategy for each: individuals who care about the environment (ie, the "public that cares"), people of influence, communities affected by environmental risks,

and individuals who do not hold strong views about environmental protection (ie, the “neutral public”).

In the short term, the “Environment Matters to Your Health” campaigns should focus on messages that concern policies and individual actions that are most readily implementable and feasible. In the longer term, the campaigns should encompass policies and actions that will contribute the most to reducing environmental impacts on health.

## Next Steps

North Carolina has demonstrated important leadership in policies, research, and community engagement to protect public health from environmental risk factors. Furthermore, North Carolina is home to some of the leading research institutions focused on understanding and reducing environmental impacts on health (Table 1). Nonetheless, the state’s poor scores on important public health and environmental indicators suggest that much work remains. The North Carolina Environmental Health Summit produced a menu of options that the state can pursue toward the goal of preventing diseases of major importance that are triggered or exacerbated by environmental exposures. Reducing the prevalence of these preventable diseases has the potential to substantially decrease state health care spending over the long term. North Carolina can serve as a national model for reducing the prevalence of preventable diseases and decreasing state health care.

In an era of severe budget constraints, costly new state initiatives are unlikely to be pursued. Therefore, as a next step, the Environmental Health Summit participants recommended that the Research Triangle Environmental Health Collaborative convene an interagency work group that includes community representatives and agency personnel to prioritize the many possible activities represented in the Environmental Health Summit’s menu of recommendations. This work group also could determine potential funding sources for the priority initiatives, to prevent short-term state budget increases while recognizing the substantial potential for these initiatives to decrease costs to the state budget over the long term. **NCMJ**

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## Acknowledgments

Potential conflicts of interest. All authors have no relevant conflicts of interest.

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# Neighborhood-Specific Epigenome Analysis: The Pathway Forward to Understanding Gene-Environment Interactions

*Kenneth Olden, Lydia Isaac, Lynn Roberts*

**Morbidity and mortality associated with complex diseases are expected to increase as the population ages and the number of Americans living in poverty continues to expand. Therefore, improved translation of research findings into clinical practice and public health policy must become a priority. This commentary emphasizes the need for a new research model that accommodates the complex nature of disease etiology.**

**C**omplex diseases such as asthma, cancer, diabetes, and cardiovascular disorders account for a disproportionate percentage of health care costs in the United States and other industrialized nations [1]. Furthermore, morbidity and mortality associated with such diseases are expected to increase as the population ages and the number of Americans living in poverty continues to expand. Therefore, improvement in translation of medical research findings into the practice of medicine and public health policy and practice must become a national priority. This commentary emphasizes the need for a new research model that takes into consideration the complex nature of disease etiology. The current “bench to bedside” model must be expanded to include the “community,” as well as transdisciplinary research that integrates knowledge of genetics and epigenetic regulation with information about environmental exposures, broadly defined to include social, behavioral, economic, and physical/chemical factors.

We know that the link between the environment and population health is strong. In fact, the World Health Organization estimates that approximately a quarter of the global burden of disease is related to environmental risk factors [1]. Most of the advances in population health during the past 150 years have been due to changes in the physical environment. Measures such as improvements in sanitation, air quality, and food safety and the creation of public drinking water systems have been implemented to address some of the problems introduced by these changes, but many problems persist. We also know, for example, that ambient levels of pollutants in the air we breathe can cause or exacerbate respiratory health problems, cardiovascular disease, and cancer; that water pollution can lead to acute poison-

ings or have longer-term, chronic effects; and that the environments in which we work, live, and go to school contribute to health disparities. Although researchers and public health practitioners have long known about the links between the environment and population health, insufficient attention has been given to the environmental changes and public health policies necessary to improve both individual health and population health.

A decade after the completion of the Human Genome Project, many disease-susceptibility genes have been discovered, yet the causes of most common diseases still remain unexplained. To date, hundreds of thousands of genetic variants have been examined in disease-association studies. Unfortunately, most of the variants have only modest effects on disease susceptibility. Most of these studies were designed to detect main effects of variant alleles; thus, they are too small to detect gene-environment interactions. Furthermore, the genetic model of disease does not explain several features of complex diseases. These include the high degree of discordance or dissimilarity in susceptibility (often as high as 85%) and variability in age of onset and severity of disease among monozygotic twins, since they share the same genes (both susceptibility and modifier). Moreover, a large body of evidence now exists indicating that environmental, social, behavioral, and economic factors are important determinants of health [2, 3]. The emerging view, from the disparate studies conducted during the past 30 years, is that neither genetics nor environmental factors acting alone cause complex diseases, but rather that they are caused by complex interactions involving the various determinants. Therefore, to improve the health of individuals and populations, research is needed to elucidate gene-environment interactions.

Despite the fact that the concept of gene-environment interaction is now widely accepted, the vast majority of social and behavioral, environmental, and genetic research

Electronically published May 20, 2011.

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is still conceptualized and conducted within narrow disciplines by investigators with expertise in a single area. Given the complexity of regulatory networks involved in the development of human diseases, it is highly unlikely that stand-alone disciplinary analysis will provide the insight needed for their prevention or cure. The research approach called for here will require a shift in focus to transdisciplinary teams that involve researchers with expertise in the requisite disciplines needed to develop an integrated, holistic effort to untangle the complex interactions involved in the etiology of complex diseases.

The slow pace of progress in understanding the causes of common diseases is related, at least in part, to the fact that the scope and scale of the models used do not recapitulate the known complexity of disease etiology. For example, most studies designed to understand variation in predisposition to disease have not taken into account the fact that gene expression is regulated by DNA nucleotide sequence and chemical modification of the epigenome and that most, if not all, diseases are caused by interactions between the genome, the epigenome, and the environment. Therefore, an important layer of complexity and a possible source of variation have not been integrated into experimental models.

The epigenome refers to the sum total of all the chemical modifications of DNA and chromatin that are not encoded in the nucleotide sequence of DNA, and epigenetics is the study of such heritable changes. "Epi" is derived from a Greek word meaning "over," "above," or "on top of." Waddington coined the term *epigenome* in 1942, as a conceptual model of how genes, though not yet discovered, might interact with their environment [4]. The epigenome can be viewed as a code that is superimposed on the genetic code, to choreograph gene expression in response to signals derived from the environment. Even though all the information required for the synthesis of all the proteins in the human body is encoded in the DNA, only a small fraction of the total repertoire is expressed at any given time or place.

The epigenome operates at the interface between genes and the environment, playing a pivotal role in mediating cross talk between the environment and the genome. It is now well-established that many environmental exposures (both social and physical) can modify the structure of the epigenome. The most common modifications involve methylation of DNA or histone proteins associated with chromatin. The addition of methyl or other small chemical molecules to DNA or chromatin either blocks or promotes binding of the enzyme complex responsible for transcription of DNA into RNA. The net effect of restricting or exposing new DNA-binding sites is that gene expression and predisposition to disease can be altered.

Unlike the genome, which is the same in every cell and tissue in the human body, the epigenome is highly variable over the life course, from tissue to tissue and from environment to environment. Also, unlike genes that are inactivated by nucleotide sequence variation, genes silenced by epigenetic

mechanisms are still intact and, thus, retain the potential to be reactivated by environmental or medical intervention.

The phrase "gene-environment interaction" implies that the direction and magnitude of the effect that a genetic variant has on the phenotype can vary as the environment changes. One can envision the existence of a finely tuned epigenetic mechanism that can switch genes "on and off," shifting the phenotype within a genetically defined range as the environment changes [5]. This buffering mechanism allows humans or other organisms to cope with environmental heterogeneity, to improve their fitness for survival. In fact, survival is threatened when living organisms lose their ability to change their phenotype in response to environmental stressors. Whereas epigenetic regulation of gene expression may have evolved to improve fitness for survival in variable environments, changes in gene expression at an inappropriate time or place may lead to disease. Also, the intensity of the environment-induced stress may overwhelm the compensatory capacity of buffering mechanisms. Environment-induced epigenetic changes in gene expression are the most plausible causes for the observed discordance in susceptibility to diseases among genetically identical (monozygotic) twins.

It is likely that human activity and the introduction of new technologies during the past 100 years have led to the build up of harmful by-products in the environment faster than biological systems can evolve buffering or repair systems to ameliorate them. It is also possible that some genetic variants that once endowed the human species with survival or reproductive advantage, and were therefore adaptively selected during the course of human evolution, now increase risk for disease because of their incompatibility with the modern-day environment. These social and evolutionary trends are likely significant contributors to both the development of the epidemic of chronic diseases and the epigenetic mechanisms to promote adaptation and survival. For example, the rapid increase in the prevalence of type 2 diabetes is surely the result of recent environmental changes (eg, abundance of food) and behavioral changes (eg, sedentary lifestyle) interacting with a relatively constant genetic background that consists of approximately 25 known susceptibility genes.

It is well established that abnormal DNA-methylation patterns are associated with many human diseases and disorders—including cancer, obesity, type 2 diabetes, anemia, cardiovascular disorders, and many neurodevelopmental disorders [6]—further suggesting the importance of epigenetic regulation in the development of human diseases. If environment-induced epigenetic regulation of gene expression proves to play a prominent role in determining susceptibility to common diseases, opportunities to prevent their occurrence would be greatly enhanced by exploiting the dynamic and reversible plasticity of the epigenome.

Even though social and neighborhood factors are among the most powerful predictors of health outcomes, efforts to integrate such knowledge with improved capacity to assess



genetic susceptibility have been limited. The fundamental principle of environmental justice is that social, behavioral, and neighborhood factors matter for health. Neighborhoods are more than groups of people living in a common geographic space—they represent complex environments in which cultural, economic, and physical factors interact in unique ways to influence disease risk. Failure to account for neighborhood differences in study design may account for why most of the variance in disease risk is still unexplained and why strong candidate genes often perform poorly in genotype-phenotype association studies.

We need to take advantage of the much-celebrated neighborhood diversity characteristic of major US cities to develop models of differing exposures. This can be achieved by developing a database consisting of neighborhood-specific epigenetic markers in parallel with genetic, environmental, and gene-expression data. The prediction is that research will detect significant interindividual and neighborhood-specific epigenetic variation that regulates the expression of genes with important roles in disease development and that can be correlated with specific interactions between the genome, the epigenome, and the environment. **NCMJ**

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### **Acknowledgments**

Potential conflicts of interest. All authors have no relevant conflicts of interest.

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# The North Carolina Clean Smokestacks Act

*William G. Ross Jr.*

The story of North Carolina's Clean Smokestacks Act is a story about the link between the environment and health. It is a story about the good things that can happen when a state looks at health care policy through the lens of environmental health. For North Carolina, those good things are cleaner air and better health, for people and the environment, from Clingman's Dome to Jockey's Ridge.

## Environmental Health: The Link That Changed the Game

In the 1990s, many citizens and organizations, in North Carolina and elsewhere, had growing concerns about the harmful effects of air pollution on people and the environment. Although the country had made much progress in air pollution control through decades of regulatory actions and technological advances, there was a growing body of disturbing evidence about deteriorating air quality and previously unknown effects of air pollution on health and welfare [1]. Many people were worried about what ozone, haze, smog, tiny particles, acid rain, and nitrogen deposition were doing to mountain ridges and valleys, to piedmont cities and towns, to coastal communities and waters, to forests and streams, to scenic vistas and wildlife, and to people, whether young or old, healthy or vulnerable, or advantaged or disadvantaged. They knew that a leading source of these different pollutants or their precursors was the coal-fired power plants of their state, the region, and areas upwind.

In 1992, in response to specific concerns that declining air quality in the southern Appalachian Mountains was adversely affecting the natural resources of the mountains, particularly the national parks and wilderness areas, 8 southern states, including North Carolina, and various partners began a pivotal, decade-long modeling study of air pollution in the region. Called the Southern Appalachian Mountains Initiative (SAMI), the study was voluntary, collaborative, and innovative [2].

As the SAMI investigators looked at the effects of ozone and fine particle pollution on the natural resources of the region, public health investigators were looking at the impact of the same pollution on the human resources of the region. Scientific evidence was mounting that declining air quality in the region was adversely affecting not only the health of the natural resources, but also the health of the people. Numerous studies linked ground-level ozone, tiny particle

pollution, or both to a long list of human health effects, including premature mortality, hospital admissions for respiratory and cardiovascular problems, emergency department visits for asthma, nonfatal heart attacks, lower- and upper-respiratory tract illness, lost work days, lost school days, minor restricted-activity days, asthma exacerbation among asthmatic populations, and respiratory exacerbation among asthmatic populations.

As the new century began, concerns about the effects of pollutants on the health of people and the environment grew stronger, as did awareness that environmental changes were necessary to improve population health. Numerous individuals and organizations across the state urged the legislature to act. The concerns were especially strong in western North Carolina, and they helped convince then-State Representative Martin Nesbitt and then-State Senator Stephen Metcalf that action was needed. The 2 prepared a bill that would significantly reduce emissions of nitrogen oxide (NO<sub>x</sub>) and sulfur dioxide (SO<sub>2</sub>) from North Carolina's 14 coal-fired power plants. The bill went beyond the requirements of the federal Clean Air Act and came to be known as the North Carolina Clean Smokestacks Act [3]. The state Senate passed an initial version of the bill in 2001, but it stalled in the state House of Representatives because of questions about its effects on utility rates.

Although the bill stalled, concerns about health and the environment did not. When Mike Easley, governor of North Carolina at the time, hosted the regional 2002 Governors' Air Summit, on May 10, 2002, in Charlotte, North Carolina, a large crowd turned out to express their concerns and urge action [4]. At the summit, people's concerns and the scientific evidence about the human health and welfare effects of the region's decreasing air quality converged in a game-changing way.

Harold Reheis, director of the Georgia Environmental Protection Division, presented the findings of the 10-year SAMI study. SAMI modeling provided clear and compelling evidence that North Carolina would gain substantial ben-

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Electronically published May 20, 2011.

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**NC Med J. 2011; 72(2):128-131.** ©2011 by the North Carolina Institute of Medicine and The Duke Endowment. All rights reserved. 0029-2559/2011/72208

efits from the Clean Smokestacks Act, regardless of what happened in other states. Previously, one of the arguments against the bill was that it would not do much good because the primary problem was pollution from other states. SAMI showed that each state would benefit most from reducing emissions within its own boundaries. It also showed that the cuts would yield benefits across the state, not just in the mountains.

Clay Ballentine, a physician from Asheville, North Carolina, and Leah Devlin, who was then the North Carolina state health director, presented evidence that the health benefits of the Clean Smokestacks Act would be significant. Ballentine reported on a unanimous 2001 resolution from the North Carolina Medical Society that urged all branches of state government to work toward cleaner air because of the large public health impact of exposure to air pollution. Devlin spoke about the public health imperative of reduced emissions and cleaner air.

The combination of SAMI findings and evidence of adverse effects on human health and welfare made a compelling case that each state should control its own coal-fired power plant emissions. People felt that something had to be done. The governors urged action across the region.

After the summit, the debate about the Clean Smokestacks Act in North Carolina was no longer focused on need, but squarely on costs. Governor Easley and legislators met with utility companies and other stakeholders, in an effort to develop a compromise that could win support in the House. Out of the negotiations came a revised bill that would freeze electric rates for 5 years, while allowing utility companies to accelerate the write-off of their costs for installing new pollution controls, which they estimated to be \$2.3 billion.

The compromise broke the stalemate, and the bill moved forward. The North Carolina General Assembly passed it by overwhelming margins, and Governor Easley signed the North Carolina Clean Smokestacks Act into law on June 20, 2002. North Carolina had looked at the strong link between environment and population health and had enacted a precedent-setting law that promised cleaner air and better health by controlling multiple pollutants.

### The Requirements of the Clean Smokestacks Act

The act required the 14 coal-fired power plants of Duke Energy and Progress Energy to achieve a 77% cut in NOx emissions by 2009 and a 73% cut in SO<sub>2</sub> emissions by 2013. NOx is a main ingredient in ozone, one of North Carolina's biggest air quality problems, and it contributes to particle pollution, haze, and acid rain. SO<sub>2</sub> is a main ingredient of tiny particle pollution, haze, and acid rain. These same cuts were expected to reduce mercury emissions significantly, as a co-benefit.

An important feature of the Clean Smokestacks Act was that Duke Energy and Progress Energy were required to achieve the emissions cuts through actual reductions at their 14 North Carolina power plants—not by buying or trad-

ing emissions credits from utility companies in other states, as is allowed under federal regulations. Also, the companies were required to reduce their NOx emissions year-round, not just during the summer ozone season, as under federal requirements.

### Successful Implementation of the North Carolina Clean Smokestacks Act

On June 1, 2010, Dee A. Freeman, secretary of the North Carolina Department of Environment and Natural Resources (DENR), and Edward S. Finley Jr., chairman of the North Carolina Utilities Commission, reported to the North Carolina General Assembly on the implementation of the Clean Smokestacks Act. The news was good. The DENR and the commission concluded that the actions taken through June 1, 2010, by Duke Energy and Progress Energy were in accordance with the provisions and requirements of the act. The report detailed the successful implementation of the law:

2007 marked the first step in meeting the emission reductions required by the Clean Smokestacks Act. Specifically, Duke Energy is limited to 35,000 tons of oxides of nitrogen (NOx) in any calendar year beginning 1 January 2007, and Progress Energy is limited to 25,000 tons of NOx. Both utilities reported to have met their respective limits as recorded through continuous emission monitoring (CEM) data. ... The end of 2009 marked the second milestone in emission reductions, when Duke Energy had to further reduce its calendar year NOx emissions to 31,000 tons, and both utilities were required to reduce their calendar year sulfur dioxide (SO<sub>2</sub>) emissions, Duke Energy to 150,000 tons and Progress Energy to 100,000 tons. Both utilities reported that they have met their respective limits for 2009, which has been confirmed by DENR staff. The next milestone in emission reductions occurs in 2013, when Duke Energy and Progress Energy must reduce their annual SO<sub>2</sub> emissions to 80,000 tons and 50,000 tons, respectively. Duke Energy's SO<sub>2</sub> emissions were below the 2013 cap in 2009. Progress Energy is expected to meet this target with the recently planned retirement of the Lee coal-fired power plant and its replacement with a combined-cycle natural gas fired plant [5p2].

Two graphs from the North Carolina Division of Air Quality (DAQ) illustrate the dramatic reductions in SO<sub>2</sub> emissions (available at: <http://daq.state.nc.us/news/leg/so2.jpg>) and NOx emissions (available at: <http://daq.state.nc.us/news/leg/nox.jpg>) [6]. For mercury, the commission

**FIGURE 1.**  
Levels of Ozone in North Carolina, 1990-2009

This figure is available in its entirety in the online edition of the NCMJ.

Note. National Ambient Air Quality Standards (NAAQS) are established by the Environmental Protection Agency under the authority of the Clean Air Act and apply to outdoor air throughout the country. Levels are based on the annual fourth highest 8-hour maximum value recorded. 2009 data are preliminary.

stated that “[t]he controls needed to comply with the North Carolina Clean Smokestacks Act provide significant co-benefits in the form of mercury emissions reductions” [5]. In fact, DAQ Director Sheila Holman indicated that mercury emissions from the coal-fired power plants of Duke Energy and Progress Energy decreased from 3,581 pounds in 1999 to 1,987 pounds in 2008 (S. Holman, e-mail communication, March 4, 2011).

### Breathing Better, Dying Later

Now, almost a decade after the enactment of the Clean Smokestacks Act, the citizens of North Carolina are receiving the benefits of cleaner air and better health. Reduced emissions brought about by the Clean Smokestacks Act, in concert with several other state and federal programs to control air pollution, have resulted in significant reductions in levels of important air pollutants in North Carolina. By use of its network of air quality monitors, the DAQ has measured the decrease in the ozone level (Figure 1, available only in the online edition of the NCMJ) and the fine particle level (Figure 2, available only in the online edition of the NCMJ) [6]. “North Carolinians are breathing cleaner air and seeing bluer skies because of the Clean Smokestacks Act,” said Holman. “The act has led to substantial reductions in emissions that cause ozone, haze, particle pollution and other air quality problems.”

As North Carolina has done the hard work of cleaning up its air at home, the scientific evidence supporting the health and welfare benefits of the cleanup have grown stronger and clearer. Here are 2 brief examples.

As noted above, the SAMI found that emissions reductions applied in a particular state would generate the most benefits in that state. That finding had an important role in convincing legislators who were considering the Clean Smokestacks Act to move ahead. The same finding, with respect to the benefits of controlling fine particle and ozone pollution, is now broadly recognized, as demonstrated in an article recently published in *The Economist*, which remarked that “[t]he benefits in terms of breathing better and dying later accrue mostly to the country that is doing the cutting” [7].

Finally, the Clean Smokestacks Act recently contributed to another victory for cleaner air and better health, not just in North Carolina but across the southeastern United States. The act directed the state to use “all available resources” to effect similar reductions from sources in other states, “including the Tennessee Valley Authority” (TVA) [3]. Consequently, the North Carolina Attorney General sued the TVA in 2006, alleging that emissions of SO<sub>2</sub> and NO<sub>x</sub> from the TVA’s coal-fired power plants were a public nuisance.

On April 14, 2011, the EPA, the TVA, North Carolina, Alabama, Tennessee, Kentucky, the National Parks Conservation Association, the Sierra Club, and Our Children’s Earth Foundation announced a far-reaching air quality settlement that will result in emissions reductions

**FIGURE 2.**  
**Levels of Fine Particles in North Carolina, 2000-2009**

This figure is available in its entirety in the online edition of the NCMJ.

Note. National Ambient Air Quality Standards (NAAQS) are established by the Environmental Protection Agency under the authority of the Clean Air Act and apply to outdoor air throughout the country. Levels are annual averages. 2009 data are preliminary.

across the TVA system that are substantially equivalent to those required by the Clean Smokestacks Act. As James C. Gulick, senior deputy attorney general, reported to the North Carolina Environmental Management Commission on May 12, 2011, the air quality benefits of the agreement to North Carolina will be great. They include substantial health benefits, environmental benefits associated with reduced acid deposition and improved visibility, and economic benefits [8].

Although North Carolina has not estimated the health benefits of the emissions reductions under the settlement agreement, the reductions will exceed those sought by North Carolina in the nuisance case. In that case, the state’s experts meticulously estimated the annual health benefits in North Carolina associated with the emissions reductions the state sought. According to these estimates, the reduced emissions would result in 99 fewer premature deaths; 20 and 40 fewer hospital admissions for treatment of cardiovascular disease and respiratory disease, respectively; 57 fewer visits to the emergency department; 43 fewer cases of chronic bronchitis; 19,000 fewer cases of asthma exacerbation; 47,000 fewer minor-restricted-activity days; and 2,300 fewer lost school days [8].

H. Kim Lyerly, a physician at Duke University Medical Center, sees the Clean Smokestacks Act story as a sign of things to come. “There is an increasing appreciation of the impact of the environment on the behavior of cells. The potential health impact of these behavioral changes may range from preventing the normal development of critical tissues, to the promotion of cancer. A methodical and systematic look at the biologic effects of these environmental changes is critical.” **NCMJ**

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### Acknowledgment

Potential conflicts of interest. W.G.R. has no relevant conflicts of interest.

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# Use of Spatial Analysis to Support Environmental Health Research and Practice

Marie Lynn Miranda, Sharon E. Edwards

Recent advances in spatial statistics and geographic information systems provide innovative platforms for diagnosing environmental health problems and for developing interventions. This article discusses when and where spatial techniques can most effectively be deployed to address environmental health issues, especially as they relate to environmental justice concerns.

**M**any health outcomes are shaped by multiple and interacting factors, including social, environmental, and host-factor influences. Current intervention programs and supporting databases are not designed to make the connections between contributing factors and to provide an integrated approach to environmental health research and practice. These limitations hamper our ability to disentangle the complex etiologies of environmental health concerns—often restricting our progress in addressing environmental justice issues. By integrating multifactorial components into a comprehensive model, geographic information systems (GIS) technology and spatial statistics facilitate innovative strategies for improving environmental and public health.

The key to spatial analysis is that most data contain a geographic component that can be tied to a specific location, such as a state, county, zip code, census block, or single address, as well as to more ecologically oriented geographic features, such as a watershed, airshed, floodplain, and riparian zone. Geographic analysis enables users to explore and overlay data by location, revealing hidden trends that are not readily apparent in traditional spreadsheet and statistical packages. GIS allows for the construction of space (and space-time) data architectures that can then be analyzed with either spatial or aspatial statistics. Analytical results can then be displayed in GIS, to enhance ease of interpretation. Additionally, GIS contains advanced capabilities to generate clear and accessible maps and data reports that can serve as powerful tools for research, outreach, and policy design.

The literature on the use of GIS and spatial statistics in addressing environmental health is extensive and growing rapidly [1-4]. In this article, we discuss 3 North Carolina-based applications that demonstrate the power of GIS and spatial analysis in advancing research, conducting community outreach, and shaping policy design.

## GIS, Spatial Analysis, and Research

Researchers have used GIS and spatial statistics in a variety of environmental health applications, including air quality, water quality, pesticide exposures, vector control, and the built environment [1, 3-7]. One key question that often emerges in environmental health research is how to link health outcomes with exposure data. As long as the health outcome data include some geographic reference, GIS allows for the linkage of outcome and exposure data via shared geography. For example, Figure 1 shows the Environmental Protection Agency's (EPA's) Air Quality System (AQS) particulate-matter monitors in the Charlotte, North Carolina, metropolitan area. AQS monitors are located across the country and collect data on ambient levels of the 6 criteria air pollutants: carbon monoxide, lead, nitrogen dioxide, particulate matter, ozone, and sulfur dioxide. Exposure to criteria air pollutants can adversely affect health; thus, the EPA regulates these pollutants, using the AQS monitoring data to determine areas that are out of compliance with established standards [8].

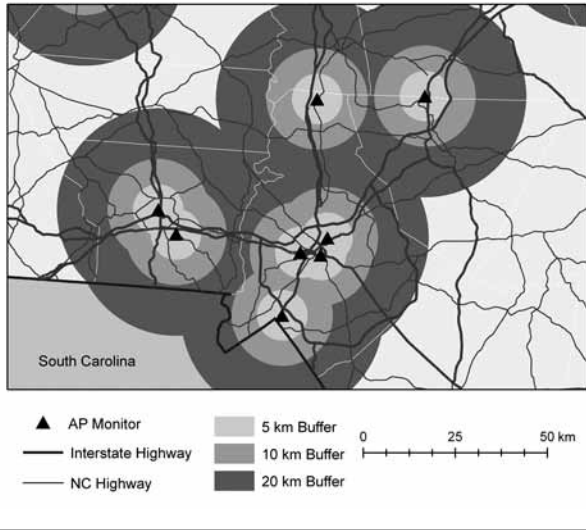
In Figure 1, we construct 5-, 10-, and 20-km radial buffers around each of the active monitors. If clinical or vital records data are spatially referenced, the intersection between locations associated with health outcomes and the radial buffers can be calculated. This allows researchers to link the health outcome data spatially and temporally with the monitoring data. The appropriate size of the radial buffer and the temporal scale for the exposure profile depend on the nature of the pollutant and its fate and transport patterns, as well as on the particular health end point under consideration. An alternate measure of exposure to air pollution can be constructed using road network data, which is also displayed in Figure 1. Continuous measures, such as distance to a major roadway, as well as categorical measures, such as locations within a certain number of meters of a major roadway, can both be used to provide a global proxy for exposure to

Electronically published May 20, 2011.

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**NC Med J. 2011;72(2):132-135.** ©2011 by the North Carolina Institute of Medicine and The Duke Endowment. All rights reserved. 0029-2559/2011/72209.

**FIGURE 1.**  
**Air Quality Monitors in the Charlotte, North Carolina, Metropolitan Area, With Radial Buffers and Major Roadways**



mobile-source emissions. These approaches become especially powerful if data are available on an individual's residence location, place of work, and commuting patterns. The road network data do not restrict the researcher to locations where active monitoring is occurring, but, of course, they also do not provide an actual measure of ambient air quality.

Figure 1 provides one possible application of GIS in environmental health research, but similar methods are equally relevant for addressing questions such as drift exposure to pesticides, groundwater contamination of well water from industrial activities, surface-water contamination from rain-fall-event runoff, and exposure to contaminated sites.

### GIS, Spatial Analysis, and Community Outreach

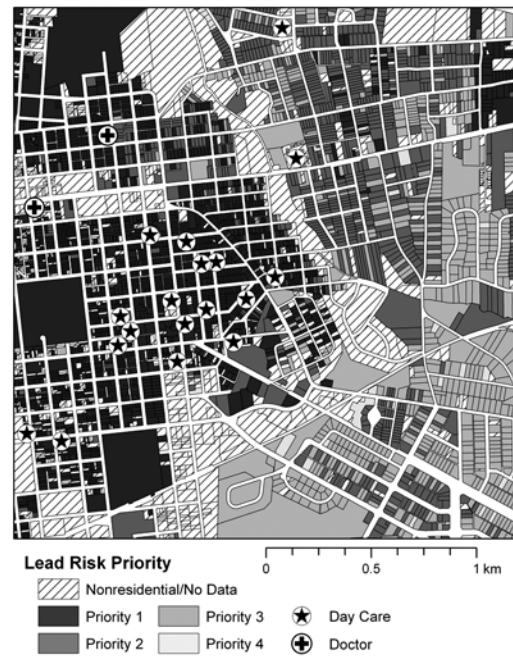
A significant body of recent research has focused on methods for implementing environmental and public health interventions more efficiently, by identifying people at the highest risk for the health effects associated with environmental exposures [3, 9-11]. GIS and spatial analysis are especially helpful for directing community outreach activities, both because they help target interventions and because GIS maps serve as a powerful communication tool in trying to reach communities at risk. For example, a number of analyses have sought to reduce the costs and improve the detection rate of blood-lead screening [12, 13]. These analyses have attempted to target blood-lead screening efforts by identifying the children or groups of children who are at the highest risk of lead exposure.

Figure 2 presents a map of part of New Hanover County, North Carolina. The risk model shown in the map combines county tax assessor data, blood-lead screening data from clinic visits, and US Census data, to create household-level

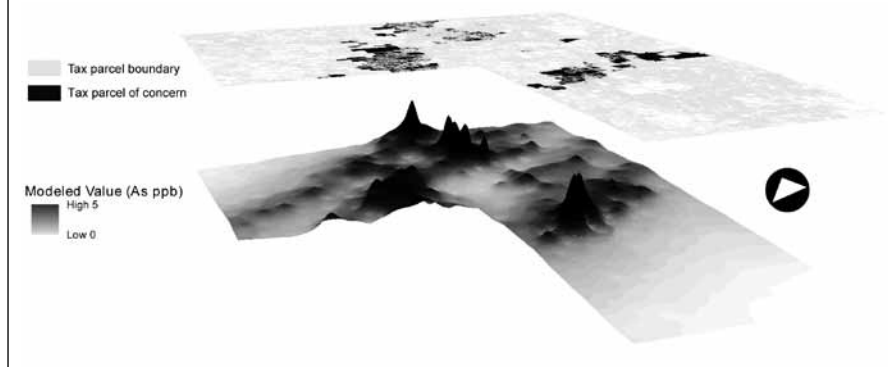
priority models for childhood lead exposure [10, 14]. The darker the color of a given tax-parcel polygon, the higher the relative risk for exposure to lead. The model depicted in Figure 2 was validated by the collection of environmental sampling data, to confirm that locations with high environmental lead samples correspond with areas of high relative risk for lead exposure and, conversely, that low environmental lead samples correspond with areas of low relative risk for lead exposure. The map also shows the location of local community resources that can serve as the venues for launching outreach activities. These models have been used in communities both to direct blood-lead screening programs and to prioritize the expenditure of housing rehabilitation funds.

The products of GIS-based statistical analyses can serve as the basis for enhanced communication with local communities. The presentation of voluminous tabular data makes it difficult for community members to make sense of the data and to act on the message of the data in motivating, designing, and implementing public and environmental health interventions. In contrast, GIS maps summarize both data and results of analyses in ways that are accessible and intuitive to community members, even more so now that online mapping applications are commonly used in the daily lives of people of all races and income classes. Thus, the GIS applications strengthen the ability of communities to self-advocate.

**FIGURE 2.**  
**Parcel-Level Modeled Lead Exposure Risk and Relevant Community Resources in New Hanover County, North Carolina**



**FIGURE 3.**  
**Predicted Arsenic Values in Groundwater Wells >150 Feet Deep**



### GIS, Spatial Analysis, and Policy Design

GIS and spatial statistics can make important contributions to the debate on how, when, and where to implement or change environmental regulatory policies and priorities. Such applications are especially well suited to identifying areas of noncompliance or areas of elevated risk (so-called hotspots), which may highlight the need for policy change or, at the least, environmental investigation. For example, the arsenic concentration in supplies of public drinking water is regulated by the EPA. Arsenic in drinking water has received considerable public attention, with the EPA lowering the arsenic standard for public drinking water in 2001.

Despite known health effects associated with contamination of drinking water, the EPA does not regulate private wells. As groundwater from private wells is still a primary source of drinking water for more than 2 million North Carolina residents [15], understanding which private wells are at risk for potentially high levels of arsenic is a critical environmental and public health concern.

Figure 3 displays the results of a spatial random-effects model designed to predict arsenic levels in groundwater on the basis of geologic and well-construction data. This modeling effort informs policy intervention by creating 3-dimensional maps of predicted arsenic levels in groundwater for any location and at any depth. Spatial analysis like that presented in Figure 3 can serve as the basis for changing EPA regulatory policy on private wells or, more realistically, can help shape state and local policies about encouraging the testing of well water and the potential installation of point-of-use water-treatment systems. Such analysis could also serve as the basis for statewide or national policy, if developed at sufficient geographic scale.

GIS and spatial analysis approaches are equally relevant for a wide range of environmental policy concerns, including near-roadway emissions and exposures, siting of locally unpopular land uses, siting of community resources such as schools and recreational facilities, redevelopment of brownfields, effects of commercial agriculture and animal

confinement facilities, and effects of upstream activities on downstream communities.

### Concluding Thoughts

Research, community outreach, and policy design all represent substantial opportunities to employ GIS and spatial statistical approaches in public and environmental health. Relevant data sources are wide-ranging and extend to both point and areal data. We can garner important insights by linking the specific location of an individual to an exposure source (point human health data linked to point exposure data), the specific location of an individual to density maps of exposure sources (point human health data linked to areal exposure data), areal rates for disease to a specific exposure source (areal human health data linked to point exposure data), and areal rates for disease with areal exposure surfaces (areal human health data linked to areal exposure data)

Depending on the data resources available, the techniques for exploring and analyzing spatial data range from simple to highly complex. Substantial methodology has been developed to add formal inference to GIS. As a consequence, the opportunities for using GIS and spatial statistics in environmental health research and practice abound.

Environmental justice research and associated environmental justice-based calls for policy change represent areas perhaps most suited to geographic analysis. Spatial analysis and GIS map products provide an analytical basis for evaluating environmental justice claims and serve as powerful communication tools for making environmental justice claims heard in the public arena. GIS maps can be advanced by communities as symbolic representations of the need for change and can be subsequently used to track progress in improving outcomes within disadvantaged communities.

The ease of desktop GIS and the advances in spatial statistics make basic analyses both accessible and meaningful to the larger environmental health research and policy communities. The availability of rich stochastic modeling tools and high-speed computation enables much more insight to



be drawn in analyzing spatial and space-time data. In addition, more-advanced techniques, such as exposure surface modeling across space and time, downscaling of modeled output, interpolating across locations, spatial smoothing, and transport modeling, may all contribute to our understanding of the causes and consequences of environmental exposures. GIS and spatial analysis hold tremendous potential to transform how we conceive and conduct environmental health research and how we implement policy interventions. *NCMJ*

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### Acknowledgments

We thank Dana Dolinoy, Alan Gelfand, Simone Gray, Dohyeong Kim, and M. Alicia Overstreet, for collaborating with us on work that serves as the basis for the examples provided in this article, and Nancy Schneider and Joshua Tootoo, for providing geographic information systems support.

Financial support. Environmental Protection Agency (grant RD-83329301), North Carolina Department of Environment and Natural Resources (grant T07095), National Institute of Environmental Health Sciences (grant 1-R21-ES013776-01).

Potential conflicts of interest. M.L.M. and S.E.E. have no relevant conflicts of interest.

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# A Burden of Disease Approach to Prioritizing Environmental Policy Initiatives: A Case Study in the Middle East

Jacqueline MacDonald Gibson

The UNC–Chapel Hill Gillings School of Global Public Health completed a 2.5-year project to advise a rapidly developing Middle Eastern nation on strategies for reducing environmental risks to public health. The project design, which combined quantitative risk assessment with structured stakeholder engagement, provides a possible template for a strategic assessment of environmental effects on North Carolina medical care costs.

An interdisciplinary team from the University of North Carolina (UNC)–Chapel Hill Gillings School of Global Public Health recently completed a 2.5-year, multimillion-dollar project to advise a rapidly developing Middle Eastern nation on strategies for reducing its environmental burden of disease. For this project, we quantified the annual number of deaths and medical visits attributable to environmental risk factors in the sponsoring nation. Risk factors included outdoor air and indoor air pollution, drinking water and surface water contamination, heavy metals in seafood, pesticides on crops, workplace chemicals, leaking waste sites, electromagnetic fields, ozone-layer depletion, nonionizing radiation, and climate change. We then engaged local stakeholders in prioritizing risks on the basis of our quantitative assessments. We guided stakeholders in identifying and evaluating potential interventions and developing a comprehensive strategic plan for the highest-priority risks.

The methods we developed could serve as the basis for a similar project in North Carolina. A North Carolina environmental health strategic-planning exercise could identify ways to reduce state medical costs through improved environmental interventions.

This article describes how UNC–Chapel Hill became involved in this project, how we quantified the environmental burden of disease, and how we engaged stakeholders in prioritizing risks and interventions. Because of recent political changes in the Middle East, the leaders who commissioned our work wish to remain anonymous. Although they are proud of the results, they have requested that we not reveal details about their identities at this time.

## Rankings Matter

Our project originated with an unanticipated request for

proposals from the sponsoring nation's environment agency that was hand-delivered to UNC–Chapel Hill in September 2007 by the agency's secretary general (the top administrator). The request for proposals reflected growing public fear about environmental effects on health, especially cancer. The project's original advocate was an agency staff person who had lost several relatives to cancer and was concerned, like many of her fellow citizens, about possible environmental causes.

The sponsoring nation has developed at an unprecedented rate because of the rapidly growing international demand for its petroleum. Oil has brought previously unimaginable wealth but has also transformed the environment—not always for the better. Environmental damage is not yet of the same magnitude as in long-developed nations, and overall life expectancy is among the highest worldwide. Nonetheless, environmental changes have occurred so rapidly that they are perhaps more striking than those in nations that developed at a more typical pace. Roadways, factories, and skyscrapers have sprouted from formerly open deserts in time spans as short as a few months. The local lifestyle has changed, in less than a generation, from one largely based on subsistence agriculture to one in which people eat out at restaurants, spend the bulk of their time in tightly sealed, air-conditioned buildings and private cars, and communicate via extensive cellular telephone networks.

The secretary general foresaw the need to quantify the burden of disease imposed by these rapidly occurring environmental changes and to identify strategies for minimizing the potential negative health effects of continuing development. He sought scientific support from top international schools of public health, including the following US schools ranked in the top 3 by *U.S. News & World Report*: Johns Hopkins (ranked first) and Harvard and UNC–Chapel Hill (tied for second). The secretary general solicited proposals

Electronically published May 20, 2011.

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from all 3 institutions, and several months later, we received word that UNC-Chapel Hill's proposal had been selected above the others.

## Project Design

We designed a strategic planning process built on 2 key features: (1) quantitative estimates of annual deaths and illnesses attributable to each environmental risk and (2) engagement of local stakeholders in prioritizing risks and interventions. Our plan drew on methods developed in the natural and health sciences, environmental engineering, and social sciences. The Gillings School of Global Public Health is structured to minimize barriers to cross-disciplinary collaborations—a structure essential to the success of its research efforts.

**Quantifying the environmental burden of disease.** To quantify the environmental burden of disease, we expanded on an approach advocated by the World Health Organization and based on the attributable fraction (AF) concept, which is a long-standing method for analyzing health threats on a population scale [1, 2]. In brief, the fraction of disease incidence attributed to a specific risk factor is estimated as follows:

$$AF = \frac{\sum_i P_i \times RR_i - 1}{\sum_i P_i \times RR_i}$$

To apply this equation, the population is divided into  $n$  exposure levels (eg,  $n$  pollutant concentration ranges).  $P_i$  refers to the fraction of the population that experiences exposure level  $i$ , and  $RR_i$  is the relative risk of the particular disease at exposure level  $i$ .

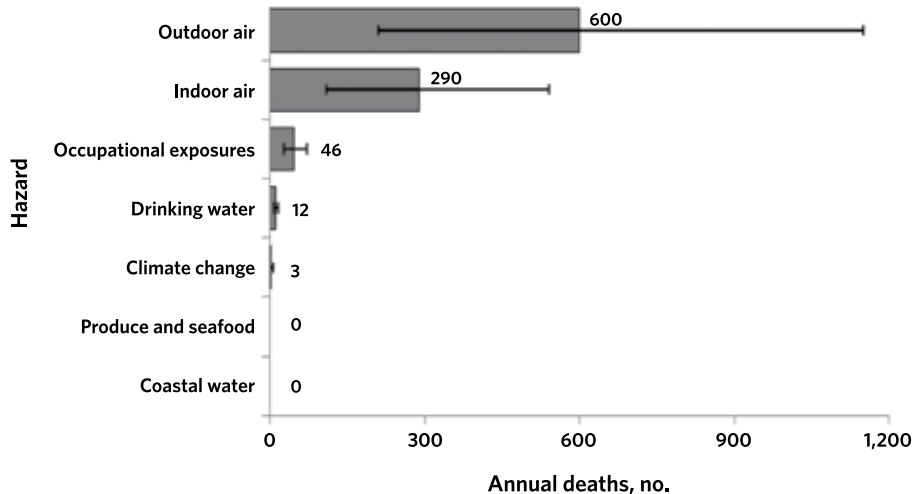
We estimated exposures by a combination of spatial analysis of environmental data (eg, pollutants measured in

ambient air and water); environmental modeling; and, when insufficient local information was available to support either of these approaches, measurement of pollutant concentrations from similar locations elsewhere in the region (eg, concentrations of methylmercury in seafood from nearby ports in other countries that fish in the same bodies of water). We obtained relative risk values from meta-analyses of global epidemiologic literature, because no epidemiologic data from the case nation existed. We combined exposure and relative risk information in a Monte Carlo simulation model that expressed uncertainty and variability in each input variable and the resulting uncertainty in our estimates. A complete description of the methods and results will be available in a forthcoming book [3].

The final step in characterizing the disease burden for a risk factor was to multiply observed disease rates by the attributable fraction. We obtained complete baseline health statistics for 2008 from the local public health agency.

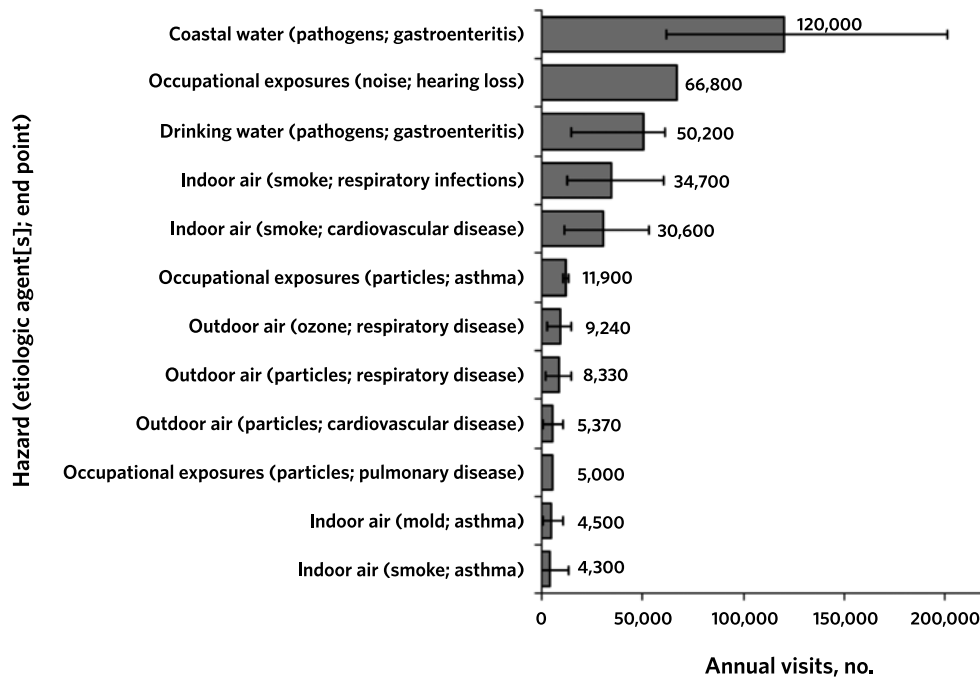
**Engaging stakeholders.** To reflect the full range of local values, we engaged stakeholders from the case nation in prioritizing risks on the basis of the quantitative risk information we had developed. We used a state-of-the-art structured stakeholder engagement process known as the Deliberative Method for Ranking Risks. This method emerged from previous comparative risk projects in the United States and is described in detail elsewhere [4, 5]. In brief, stakeholders read 4-page "risk-summary sheets" that present information about each risk factor in a standardized format. The first page includes a table displaying the number of premature deaths and the number and severity of illnesses attributed to each risk factor, including uncertainty ranges. The summary table also includes information about individuals' ability to control their exposures, latency periods, and other attri-

**FIGURE 1.** Annual Deaths Attributed to Select Pollutants and Global Climate Change in the Case Nation



Note. Whiskers indicate 95% confidence intervals.

**FIGURE 2.**  
Annual Visits to Health Care Facilities Attributed to Environmental Exposures in the Case Nation



Note. Whiskers indicate 95% confidence intervals.

butes that risk perception research has shown are pertinent to people's judgments about risks. Then, trained facilitators lead small focus groups (size, 10-12 people) through daylong sessions, to discuss and rank the risks, both individually and as a group. Results are then analyzed statistically, to determine areas of agreement and disagreement. Typically, a few high and low priorities emerge, along with areas about which stakeholders disagree, despite having access to the same risk information (reflecting differences in value judgments).

After ranking the risks, we held 3 separate workshops, each involving multiple focus groups, to prioritize interventions recommended by UNC-Chapel Hill and local scientists with expertise relevant to each risk. Interventions focused on the risks that stakeholders universally viewed as high priorities and on those about which they disagreed substantially. Some risks (eg, electromagnetic fields, nonionizing radiation, and ambient noise) dropped off the list because of lack of public health and environmental evidence that these risks occur in the population and/or because of a universally low rating of the risk by all participating stakeholders.

## Results

Figures 1 and 2 summarize our estimates of annual premature deaths and hospital visits attributable to risks retained for analysis after the ranking exercise. The predominant mortality risks are ambient and indoor air pollution—the latter primarily attributable to secondhand tobacco smoke. Leading contributors to excess illness include microbial con-

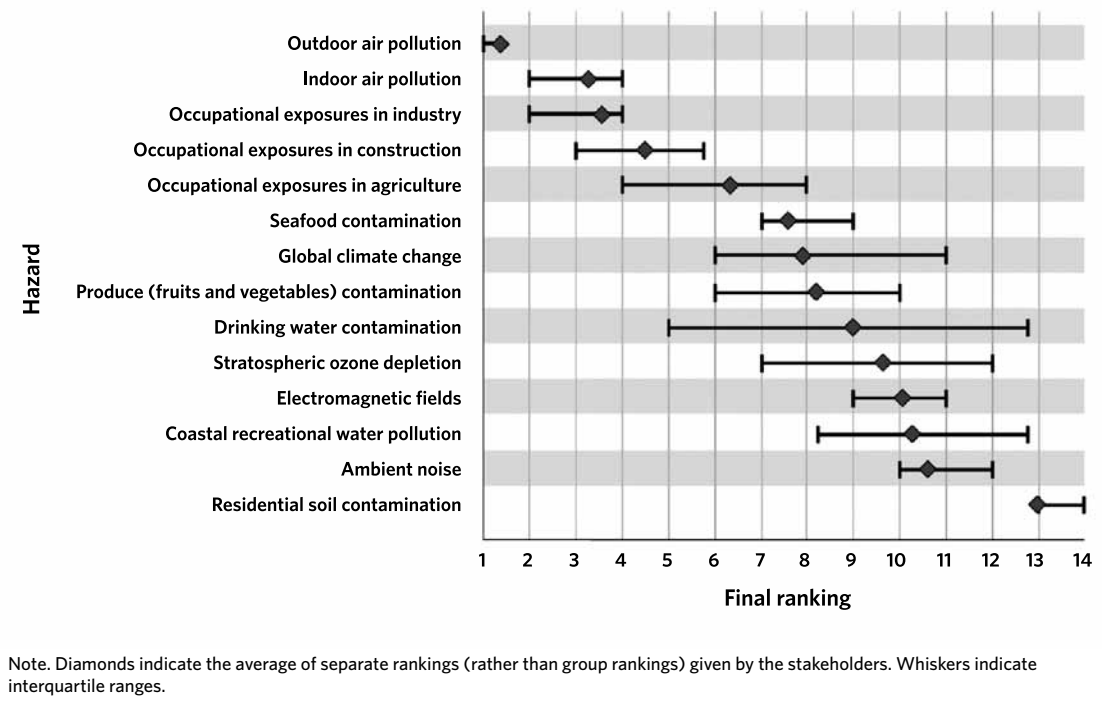
tamination of surface water (although the uncertainty range is large) and occupational exposures.

Figure 3 shows the average rankings given by focus group participants. Nearly all the stakeholders ranked ambient air pollution as the leading risk, while nearly all ranked soil contamination as of low importance. Stakeholders disagreed about priorities for drinking-water pollution, coastal water pollution, and stratospheric-ozone depletion. For drinking water, the disagreement reflected different views about the importance of water as a resource. The case nation boasts a modern public water supply that is treated with advanced European technologies, and thus the risk of waterborne disease is extremely low, causing some stakeholders to rate risks due to contamination of potable water as low. On the other hand, others said they viewed the continued protection of this vital resource as an enduring priority, particularly since fresh water is scarce in the region.

Participants at the planning workshops enumerated more than 216 actions that the nation could pursue to reduce environmental health risks. Recommended actions included strengthening environmental enforcement programs, building public rail systems, and overhauling occupational protection programs. The recommendations are summarized in a 104-page strategic plan.

Overall, the planning process and results were widely embraced by the participating stakeholders, the environment agency's leadership, and prominent national politicians. Stakeholders, on average, gave the following statement a 4.36

**FIGURE 3.**  
**Rankings of Environmental Health Hazards in the Case Nation, by 56 Environmental Health Stakeholders**



ranking on a scale of 0 (strongly disapprove) to 6 (strongly approve): “How strongly would you approve of submitting your group’s rankings to the environment agency for use in making decisions?” Unit directors at the environment agency told us the project was the best they had ever funded. We were asked to present the results to the country’s leading politician (the equivalent of a prime minister). After our presentation, he directed the secretary general to form an organization to implement the plan. The envisaged organization would have coordinated implementation across all the relevant government agencies and would have sponsored research through a new research center to improve on our initial burden of disease estimates.

Unfortunately, a major change in the government funding mechanism for such centers, combined with a change in leadership and top management at the environment agency, has derailed plans to establish the environmental health research center and implement the strategic plan. Whether the agency’s new leadership will embrace the strategic plan remains to be seen.

### Lessons for North Carolina

This project offers lessons—both cultural and political—for North Carolinians. First, we learned that citizens of this distant Muslim nation share the same desires as we do. They want a clean, safe, and healthy environment for themselves and their families. They appreciate opportunities to express their opinions about environmental health risks. Our stake-

holder engagement workshops generated vigorous debates, and to our surprise, the most outspoken participants were often women dressed in traditional veils.

Second, from a population perspective, the leading environmental risks to health are those that cause or complicate common diseases and to which exposure is widespread: cardiovascular and respiratory diseases attributable to indoor and outdoor air pollution. The fear of environmentally caused cancer, which prompted this project, while potentially important, is not the main driver of this nation’s environmental burden of disease, when considered from a population perspective. These findings are consistent with decades of research in risk perception, showing that the risks people fear the most are rarely the biggest threats to their health—that people universally underestimate high risks because they are familiar and therefore less evocative than rare events [6, 7].

At a time of unprecedented budget pressure, North Carolina should revisit the question of whether the state is investing enough in disease prevention through environmental protection. The process described in this article could provide a framework for analyzing opportunities for North Carolina to save money on medical care (eg, by reducing cardiovascular and respiratory diseases) through new or improved environmental interventions. NCMJ

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## Acknowledgment

Potential conflicts of interest. J.M.G. has no relevant conflicts of interest.

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# Integration of Environmental Stewardship and Local Economic Development to Enhance Community Health

Jay F. Levine

Environmental groups working to preserve natural ecosystems and groups working to enhance local economic development often find themselves on philosophically opposite sides of the negotiation table. Case histories of cooperative engagement are provided that serve as examples of how environmental stewardship is compatible with local economic development and community health.

## Environmental and Community Health

Natural environments are complex ecosystems defined by the interrelationships of their physical, chemical, and biological components. Components such as topography, climate, biochemical processes in soils and streams, and the availability of cover habitat for wildlife are determinants of the diversity, abundance, density, and health of the organisms that inhabit a specific environment. These components are connected and interwoven but are continually changing [1]. A change in one component affects another and can alter the health of the ecosystem and the health of the populations in residence. The built environment, whether rural, suburban, or urban, is similarly connected to the health and the well-being of its residents [2]. The choice of residence is a determinant of lifestyle. Residents of suburban communities who work in cities may have more access than urban residents to the natural environment. However, because of extended travel times, they may be getting less exercise than urban dwellers who walk to work [3]. Affluence enhances the opportunity for a person to select where they live; however, for those in poverty, there is often little choice. The built environment and the collective social environment often have individual, family, and community health consequences. Exposure to indoor environments in impoverished communities may increase the risk of lead exposure, childhood asthma, and other health problems [4]. Safety concerns and the absence of outdoor parks and other green space, or the absence of continuous connected sidewalks, may contribute to inactivity and a lack of physical exercise, which has been associated with obesity [5]. The health-related effects are often further compounded by disparities in access to affordable health care and high-quality schools. The built environment is tied to community health

[4], and community health is generally linked with the economic viability of local economies.

## Poverty, Obesity, Cardiovascular Health, and Exercise

The economic recession of the past few years has resulted in the greatest proportion of Americans living in poverty since 1994 [6]. In 2009, an estimated 43.9 million Americans were reported by the US Census Bureau to have incomes below the federal poverty level, including 20% of children. More than 14% of the US population is apparently struggling each day to put food on the table, to clothe their kids, and to keep a roof over their heads. In many communities, there is a food-availability paradox: people living in poverty have diminished food-purchasing power but are more likely to be obese. In neighborhoods with limited food-shopping alternatives, the local convenience store may be the primary venue for household food purchases [7]. Fresh produce and other healthy food products may not be readily available, and the grocery products selected may contribute to obesity. When "healthy" foods, locally grown produce, fruits, and locally prepared breads are more available, they are often more expensive and beyond the purchasing power of those living in poverty. More than 25% of the US population is estimated to have a body mass index above 30.0 and considered to be obese [8], and the percentage of obese adolescents has tripled during the past 25 years [9]. Obesity was estimated to have contributed to \$147 billion in increased medical costs and 10% of US deaths in 2008 [10].

Cardiovascular disease is the leading cause of death and reduced life expectancy in the United States. Although specific dietary recommendations seem to change frequently, obesity is a well-recognized risk factor for cardiovascular disease. Obesity is also a risk factor for diabetes, a disease that affects approximately 17.5 million people in the

Electronically published May 20, 2011.

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**NC Med J. 2011;72(2):141-144.** ©2011 by the North Carolina Institute of Medicine and The Duke Endowment. All rights reserved. 0029-2559/2011/72211

United States and may have an annual cost of more than \$170 billion [11]. Regular exercise can help with both weight maintenance and cardiovascular fitness. It builds strength, improves coordination, lowers blood pressure, helps reduce or maintain body mass index and weight, and has been associated with enhanced cognitive function and longevity [12]. When a person decides to exercise, the type of exercise and the place used for exercise is a personal choice. However, affluence again provides alternatives that may not be available to families living in poverty. Health clubs providing access to equipment for cardiovascular workouts are generally not available to economically disadvantaged families. When public natural environments (ie, green spaces) are integrated with the built environment, they are generally accessible without cost and are available to all as a community exercise resource.

### **Local Economic Development and Natural Environments**

Jobs are needed to reduce poverty and to minimize the related disparities in education, personal lifestyles, and health. Employment opportunities are driven by local economic development and related job creation. Local economic development, however, requires construction of roads, railways, and airports, which facilitate the movement of people and goods.

Each development effort affects both the already built environment and the natural environment. Decisions made in the planning and design processes affect energy use or have a physically altering effect on natural ecosystems. The initial effects, during construction, that alter the physical environment and displace resident wildlife are usually quite visible. However, secondary cumulative effects of construction may be more systemically consequential. The effects of storm events may be heightened by the loss of impervious surfaces, as new driveways, parking lots, and the roofs of residential and commercial buildings are constructed [13]. The related loss of permeable surface area reduces the potential to mitigate nutrient input and storm-water volume and often results in soil erosion, disruption of natural riparian buffers, and increased sedimentation. Consequent changes in stream hydrologic characteristics and sediment deposition alter stream habitat, reduce the availability of spawning sites for stream fauna, and drive changes in species presence and diversity.

The natural environment, our heritage, fortunately has advocates whose advocacy moderates the actions of developers and works to minimize the impact of expansion of the built environment on the natural environment. Unfortunately, these core beliefs often place developers and environmentalists on distinctly different sides of the table. The clashing objectives of community groups that drive economic development and environmentalists often divide communities. Do we support the creation of jobs that can help reduce poverty, or do we protect fish, freshwater mus-

sels, foxes, snakes, and other wildlife? At times, construction efforts may disproportionately affect a group that might not have the resources needed to choose where they live, to influence whether construction will take place, or to guide the design of the project. The groups that realize the least benefit from the project may be those who are affected the most by it. Labels often define these opposing sides (eg, “developers” and “tree-huggers”). The arguments become rhetorical, heels are dug in, and groups supporting local economic development and those supporting environmental sustainability sometimes knock each other to apparent senselessness.

For the development-oriented community, the intransigence creates project delays, elevates costs, and slows progress. For the environmental community, it creates a sense of frustration and often hopelessness that the impact on natural communities is inevitable. But these groups can work together. When environmental stewardship is an inherent philosophy helping to guide project design, it can benefit community health by providing open-space alternatives for exercise and recreation. In this manner, mutual common interest in preserving natural habitat, on the part of environmentalists and developers, can serve a broader societal function and support public health. Sustaining natural environments and creating greenways, bike paths, and parks for recreation aid the overall effort to promote exercise and contribute to efforts focused on reducing the incidence of obesity and its related health care costs. Enhancing the quality of life in a community can also benefit local economic development. Although this type of common interest and cooperation is not universal within communities, there are numerous examples where environmental stewardship has been recognized to be compatible with local economic development, as well as with environmental preservation and community health.

### **Integration of Environmental Stewardship and Local Economic Development to Enhance Community Health**

In the late 1960s, the degraded waters of the Cuyahoga River, which passes through Cleveland, Ohio, burned [14]. It was not the first time this happened—indeed, flames had been seen sporadically on the river since the 1860s—but it spurred community action. Public concern motivated civic response, and community groups and businesses accepted the challenge of cleaning up the river. Continued efforts to improve water quality in the river spawned efforts such as the Mill Creek Watershed Partnership, which has been working to improve conditions in the Mill Creek Watershed, a heavily urbanized area within Cuyahoga County that supports more than 85,000 people [15]. The partnership’s efforts embody the collective realization that environmental stewardship is compatible with economic development and community health. The initiative has been guided by the partnership’s stated goals, which include efforts to minimize flooding,



reduce soil erosion and contamination, enhance public education to improve the well-being of residents, stimulate local economic development, and improve the overall quality of life of area residents [15].

In Jacksonville, North Carolina, community and municipal recognition of the moral responsibility to restore Wilson Bay, a degraded cove in the New River, spawned the Wilson Bay Water Quality Initiative. The initiative and a related civic university and community partnership embraced the concept that environmental stewardship is compatible with local economic development. The partnership has worked to effectively improve water quality, restore wetlands, and reduce storm water input into the bay. The effort led to the development of Sturgeon City and a municipal nonprofit that guided the reclamation of a yard waste and road construction landfill into a recreational green space. The partnership has been working toward the conversion of the site of a decommissioned wastewater treatment facility into an environmental education center, Riverworks at Sturgeon City [16]. Boardwalks and pathways have been established to facilitate walks through the wetlands and park and to provide a walking connection to a local elementary school. The Sturgeon City Summer Institutes and related programs have engaged local youth in outdoor hands-on environmental learning programs, and civic volunteer activities and clubs (eg, Wilson Bay Keepers) have focused on sustaining water quality in the bay and the river.

In Wake County, North Carolina, in 2003 and 2004, local residents living within the Falls Lake Watershed expressed concern that the size of new homes being constructed, as well as the related impervious surfaces on those properties, was adversely affecting water quality in Falls Lake. Direct movement of water off of roofs and driveways was argued to be a well-recognized source of nutrient input and could lead to the eventual eutrophication of the lake and its loss as a water supply and a recreational resource. Concurrently, the county was already beginning to address the results of a study that indicated that 63% of its watersheds had already been negatively affected or degraded [17], as well as to respond to new total maximum daily load requirements set by the Environmental Protection Agency, which reflected regulatory compliance with the Clean Water Act. The county assembled a stakeholder committee, composed of 4 representatives of the environmental community and concerned county residents and 4 members representing land developers and builders. After 19 sometimes contentious meetings, the committee crafted a new residential development ordinance that embraced a commitment to sound environmental stewardship and the anticipated continued growth in residential construction needed to sustain economic development in the county. By working together, the committee created an ordinance that made a 180-degree conceptual change in how the county approached handling the design of storm water controls for new developments [18]. A traditional focus on peak flow during storm events and on

impervious surfaces was de-emphasized during the discussion, and the committee focused on reducing the volume of water discharged from development sites. The requirements accommodated low-impact design principles and focused on dispersing the water over protected natural areas, to support water infiltration and transpiration rather than concentrating it and directing it into drainage culverts and pipes. The new ordinance encouraged developers to leave portions of development property undisturbed, preserving natural environments, wildlife habitat, and opportunities for outdoor recreation.

Preserving our natural heritage is a societal responsibility and should be a priority as the built environment continues to expand and, at times, is redefined and redesigned. Jobs support economic solvency and are the main buffer helping to minimize the social injustices and unfortunate lifestyle consequences of poverty. Local economic development is needed to sustain job growth. However, in this postindustrial age, we need to continue to redefine the built environment in a manner that enhances social equity and supports the improvements in lifestyles needed to reduce obesity and the other diseases associated with poverty, as well as to support overall community health. Our collective community health benefits when environmental stewardship is considered a societal responsibility and is effectively integrated with plans for local economic development. NCMJ

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### Acknowledgments

I thank Britt Stottard for his comments and suggestions.

Potential conflicts of interest. J.F.L. has no relevant conflicts of interest.

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**Eat Smart, Move More Health Tip**



# Choose to Move More Every Day

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For more tips on how to move more every day where you live, learn, earn, play and pray, visit

[www.EatSmartMoveMoreNC.com](http://www.EatSmartMoveMoreNC.com)



# Lack of Basic Amenities: Indicators of Health Disparities in Low-Income Minority Communities and Tribal Areas

Omega Wilson

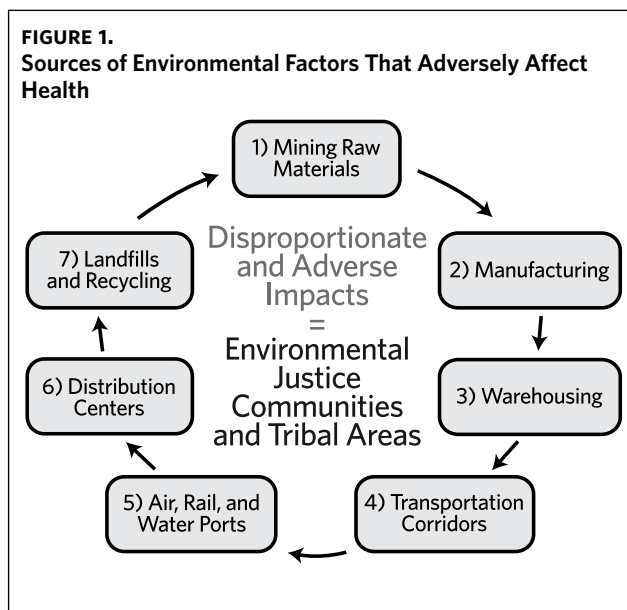
North Carolina has numerous low-income minority communities and tribal areas where basic public health amenities are lacking. Disparities in clean air, safe drinking water, and toxin-free soil create human exposures that result in poor health, depressed property value, and more contaminated environments than are present in higher income communities.

As a cofounder of the West End Revitalization Association (WERA; Mebane, NC), I have worked with legal, public health, university, foundation, and government partners to install first-time sewer and safe drinking water services, to pave dirt streets, and to remove underground storage tanks leaking petroleum and cancer-causing benzenes and xylenes [1]. As a member of the US Environmental Protection Agency's (EPA's) National Environmental Justice Advisory Council (NEJAC) during 2007-2010, I provided input on interagency policy and compliance for air, water, and soil in low-income minority communities and tribal areas. The NEJAC's Goods Movement Workgroup involved air, maritime, and rail ports and highway corridors that adversely affect low-income minority communities and tribal areas [2].

The Obama-Biden transition team requested my input, on December 16, 2008, in its Environmental Justice Forum [3]. I served as the first community planner/leader of the Community/Tribal Facilitated Strategy track at the EPA's 2010 Conference on Environmental Justice, Air Quality, Goods Movement, and Green Jobs: Evolution and Innovation. After I submitted the principles and recommendations of our community-facilitated strategies (CFS), the EPA designated WERA as the national prototype for empowering the "community voice" against transportation-corridor environmental hazards (Figure 1) [4].

## Collaborative Partnerships

To improve the quality of life in low-income minority communities and tribal areas, North Carolina must address institutional barriers of old-South cultural and racial legacies and "primacy" or "states' rights" over federal statutes. It is time to form collaborative problem-solving (CPS) partnerships that move advocacy to activism and that translate common knowledge about health disparities into effective



strategies, to eliminate hazards with measurable outcomes (Figure 2) [5].

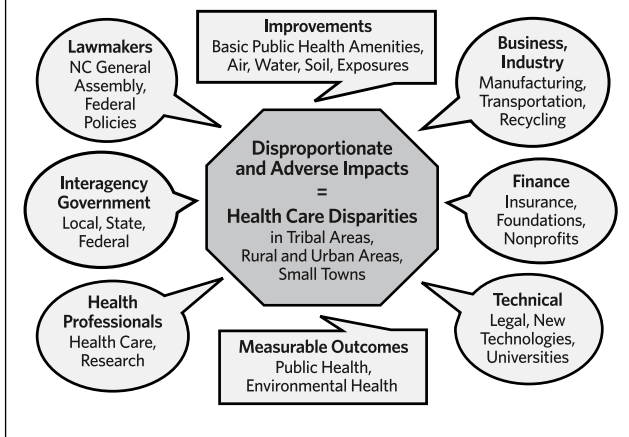
My 17 years as an environmental justice activist, a member of the North Carolina Environmental Justice Network, and a federal advisor give me an affected stakeholder's account of the denial of basic amenities and failure of enforcement of federal public health statutes. CPS partners should perform the following activities to solve public health problems associated with a lack of access to basic amenities: identify North Carolina General Assembly members, health care leaders, and industry innovators willing to sponsor a collaborative bill on health disparities and enforcement of federal public health statutes; address states' rights as a barrier to funding corrective actions in low-income, minority, and tribal areas; and educate lawmakers, public health professionals, and researchers on the legal obligations to support federal environmental policies under the National

Electronically published May 20, 2011.

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N C Med J. 2011;72(2):145-148. ©2011 by the North Carolina Institute of Medicine and The Duke Endowment. All rights reserved. 0029-2559/2011/72212

**FIGURE 2.**  
Partners to Ensure the Availability of Basic Public Health Amenities



Environmental Protection Act, federal statutes, and health care reform.

### Community-Facilitated Strategies

Low-income minority communities in the Mebane, North Carolina, area (ie, Alamance County and Orange County) are similar to other communities and tribal areas that lack basic public health amenities. The denial of or lack of access to “up-to-code” infrastructure (ie, safe drinking water, sewer collection, paved streets, sidewalks, and storm-water management) contributes to disparities in health. Long-term exposure to deficient infrastructure produces more adverse health effects in minority communities with depressed property values than are evident in white and higher-income communities [1, 4].

WERA was incorporated as a 501(c)(3) nonprofit in 1995, and it serves as Mebane’s first EPA “community-based environmental protection model” organization. It has led efforts in African American communities to stop racial discrimination and adverse effects associated with leaking underground storage tanks, unpaved streets, contaminated drinking water, failed backyard septic tanks, and landfills [1, 5-8]. Groundwater and drinking well water could be contaminated by construction of the highway and a 1-mile overpass.

In February 1999, WERA filed administrative complaints, under Title VI of the Civil Rights Act of 1964 and Environmental Justice Executive Order 12898 of 1994, at the US Department of Justice, when local, state, and federal government agencies had, for 16 years and without public input, planned construction of the Highway 119 bypass/interstate. The 4-lane highway, in an 8-lane corridor, would destroy homes and churches in 2 historic communities that had been denied access to basic municipal drinking water and sewer services [1, 5-8].

Water samples were collected from community streams by WERA and were analyzed at the University of North Carolina (UNC)-Chapel Hill Gillings School of Global Public

Health. *Escherichia coli* and other fecal coliform bacteria were detected at levels more than 300 times the standards established by the EPA’s Clean Water Act. Some residential drinking wells and Mebane’s treated water also contained *E. coli* and other fecal coliforms, in violation of the EPA’s Safe Drinking Water Act. Surface-water contamination was tracked to backyard septic systems, which had a failure rate of 50%-100% on some streets; the state average is 11% [1, 5-8].

WERA civil rights complaints, data collection efforts, and CPS partnerships helped leverage millions of dollars in block grants and municipal matching funds for the first-time installation of sewer services for more than 90 houses, for paving dirt streets, for removing underground storage tanks, and for stopping housing construction on a century-old industrial landfill. Residents have been within 2-3 blocks of a sewage treatment plant since the 1920s. The 119-bypass construction has been delayed by a construction moratorium since 1999, to seek continuing environmental-hazards mitigation under federal public health statutes and to document public input. In 3 environmental justice communities, more than 400 houses with backyard septic systems leaking human waste still need first-time safe drinking water and sewer lines [1, 5-8].

In 2008, the National Institute of Environmental Health Sciences awarded a community-university partnership grant to WERA and the Institute for Families in Society at the University of South Carolina-Columbia, to evaluate WERA’s CPS approach and its community-owned and -managed research (COMR) model, used for corrective actions, and to implement measurable results for an improved quality of life [9]. WERA received a National Environmental Justice Achievement Award from the EPA in 2008, for activism related to safe drinking water, surface water, storm-water management, dispute resolution, and civic engagement “beyond the vote” that removed environmental hazards in minority communities.

### Environmental Health Disparities

Physical pain from diseases is more readily recognized, diagnosed, and accepted. Less recognizable are the effects of despair, fear, stress, and rage, from years of discrimination and disenfranchisement. Funders encourage WERA to monitor the psychological health effects of years of struggling against old-South cultural barriers in the new South of technological advancements [1].

Successful educators, health care professionals, scientists, and government officials grew up in these polluted communities and carry the legacy of human exposures with them to very-high-income professional lives and wealthy subdivisions. Some of these individuals risk more exposure each time they visit family and friends at the old “home place.”

### Overcoming Barriers to Solutions

Mebane is recognized as the fastest-growing city in Alamance County, with developments in Orange County

**TABLE 1.**  
**Policy Priorities to reduce the Prevalence of Environmental Hazards and Disparities in Health Care**

Policy priority	Reference(s)
Implement WERA's CFS, to leverage hazard reduction or elimination through the legal protection and redress offered by federal laws.	[1, 3, 4]
Expand the "right to basic amenities movement," to improve the missing, failed, and substandard infrastructure that produces disparities in health and depressed property values.	[1]
Incorporate environmental justice and basic public health amenities in federal, state, and local laws, with measurable outcomes.	[1, 3, 4]
Remove states' rights barriers to federal funding used to challenge transportation, infrastructure, and other land use projects that can create or exacerbate environmental hazards for low-income and minority residents.	[1, 3, 4]
Remove state laws that permit or create disadvantages for residents in extraterritorial jurisdiction or unincorporated areas, including low-income minority and farmland areas, in the planning and zoning for highways, landfills, and polluting industries.	[1, 7]
Establish WERA's Right to Basic Amenities Collaborative Institute for replicating COMR, CPS, and CFS models and strategies in other low-income minority and tribal areas in North Carolina and the southeast; ground-truthing databases to measure death, suffering, and solutions in site-specific populations; and increasing the environmental literacy necessary to respond to environmental-impact statements, health-impact assessments, and human-exposure studies.	[1, 4]
Develop new policies for EPA, US Department of Agriculture, US Food and Drug Administration, and other government agencies that permit spraying or spreading of human sewage sludge on farmland to fertilize human food crops. There are increasing numbers of reports of health effects from exposure to human sludge.	[10-12]
Develop new policies to address the situation wherein university and government researchers take 50%-97% of federal grants without funding equity and management parity for environmental justice organizations and community investigators.	[1-8]
Create new policies to remediate areas where major agribusinesses, livestock farming, and manure pits disproportionately and adversely impact human health, contaminate ground water and river basins, reduce air quality, and depress residential and small-business property values.	[3, 11, 12]
Generate new policies regarding sites of raw-materials mining, landfills, and recycling centers, which are disproportionately located in low-income minority communities and tribal areas (Figure 1).	[13, 14]

Note. CFS, community-facilitated strategies; COMR, community-owned and -managed research; CPS, collaborative problem-solving; EPA, Environmental Protection Agency; WERA, West End Revitalization Association.

(the city straddles the counties' shared boundary). North Carolina has many nationally recognized resources, including heavily funded research programs at respected academic institutions; Research Triangle Park, with the EPA's Office of Air Quality and Planning Standards campus, the National Institute of Environmental Health Sciences, and the Biotechnology Center; international business and industry; and billion-dollar financial corporations. These organizations have yet to produce solutions for environmental injustices and disparities in health care.

Three environmental justice communities with which WERA's CPS partners have worked are diverse examples of chronic health and environmental disparities in terms of clean air, safe drinking water, clean surface water, toxin-free soil, and safe disposal of industrial, medical, and pharmaceutical waste. The first community is Mebane (until recently a small mill town), where plans for an 8-lane, 27-mile interstate corridor to Danville, Virginia, the widening of a railroad corridor, and local highway accesses for an industrial park have not fully valued marginalized communities, human health, or environmental safety. The second community is the Rogers Road and Eubanks Road Neighborhood Association in the Chapel Hill and Carrboro area (a high-income university setting), where some of the largest contributors to a landfill with documented contaminated residential drinking wells are UNC Hospitals and public health research facilities at UNC-Chapel Hill. The landfill breeds insects, large rats, and buzzards that deposit feces on cars, houses, and gardens. The third community is the Rural Empowerment Association

for Community Help, in Duplin County (rural area), where hogs in confined animal-feeding operations outnumber humans. Twenty hours per day, the air is filled with a pungent odor of hog waste, agribusiness chemicals, and diesel emissions from transporting live animals, rotten dead animals, and the packaged meat products for US and foreign grocery stores.

The clout of business, industry, university, and government polluters still presents a difficult challenge for current public health policies, legal leverage, and public outcry to overcome in the effort to reduce the prevalence of environmental hazards and disparities in health care. I presented 10 policy priorities to incoming staffers of President-elect Barack Obama's administration that focus on interagency actions to reduce or eliminate environmental contaminants and health care disparities, to enforce health statutes, and to generate new preventive efforts [3] (Table 1).

Cause-effect research often fails to produce conclusive evidence for environmental hazards that contaminate air, water, and soil in areas where many low-income minority residents have lived since slavery ended, in 1865. WERA's successes are demonstrated through innovative community-led models for the reduction and removal of environmental hazards, with site-specific research and legal compliance by local, state, and federal government agencies. WERA's primary focus is to use CPS partnerships to collect the scientific data needed to leverage legal compliance for the reduction of hazards that have become a way of life.

In 2007, Sarena Seifer and Ella Greene-Moton, both of

Community-Campus Partnerships for Health, stated that, "as illustrated by the COMR model, we must overcome deeply entrenched views and policies that serve to maintain university control of the research enterprise, and we must build the research capacity of community-based organizations" [15].

The Republican-led US House of Representatives proposes to cut the budget of the EPA and to relax enforcement guidelines, as well as to repeal health care reforms. North Carolina needs bipartisan support for the installation of basic public health amenities that advance health care.

My experience as a life- and health-insurance agent since 1984 continues to reveal a confidential and up-close view of personal health histories in low-income minority communities, where underwriting decisions often substantially increase premiums, reduce coverage, or result in exclusions that may be related to chronic exposures. This is only a glimpse of the increasing lifetime cost of environmental hazards and health care disparities for minorities.

Successes in the areas addressed in this commentary will require partnerships at the highest levels of government agencies; funding organizations; major medical facilities; business, financial, and industrial institutions; and universities. NCMJ

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### Acknowledgments

I thank the following partners for their collaboration: Z. Smith Reynolds Foundation; Department of City and Regional Planning, University of North Carolina-Chapel Hill (Chapel Hill, NC); North Carolina Martin Luther King Jr. Commission; Land Lost Prevention Project (Durham, NC); Next Generation of African American Philanthropists of North Carolina; Haw River Assembly (Bynum, NC); Lawyers' Committee for Civil Rights Under Law (Washington, DC); and Environmental Support Center (Washington, DC).

Presented in part: 2010 Environmental Health Summit; Research Triangle Park, North Carolina; September 28-29, 2010.

Potential conflicts of interest. O.W. has no relevant conflicts of interest.

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# Running the Numbers

*A Periodic Feature to Inform North Carolina Health Care Professionals  
About Current Topics in Health Statistics*

*From the State Center for Health Statistics, North Carolina Department of Health and Human Services  
<http://www.schs.state.nc.us/SCHS>*

## Demographic Characteristics of Individuals Residing Near Hazardous Waste Sites in North Carolina

Concerns over the potential adverse health effects posed by hazardous waste sites date back several decades, and events such as those as Times Beach, Missouri, and Love Canal, New York, propelled the issue to national importance. These concerns led to the enactment of several major pieces of legislation in the 1970s and 1980s. In 1976, the Resource Conservation and Recovery Act was passed to regulate the generation, management and disposal of hazardous waste. In 1980, Congress passed the Comprehensive Environmental Response Compensation and Liability Act to begin clean up of the most dangerous of these sites, many of which had been abandoned. The Superfund Amendments and Reauthorization Act was passed in 1986, providing additional funds for site remediation and increasing the involvement of local and state partners in prioritization and clean-up efforts. Through this legislation, the Environmental Protection Agency is required to create an inventory of all hazardous waste sites and to develop and maintain a list of abandoned sites—known as National Priority List (NPL) or “Superfund” sites—believed to be most hazardous to human health. There are approximately 1,290 NPL sites in the United States, 36 of which are in North Carolina [1].

The possible health effects of hazardous waste sites have been widely studied. Although some evidence suggests they may pose a potential threat to public health, the findings are equivocal [2]. Hazardous waste sites have been linked, although not consistently, to a wide variety of adverse health outcomes, including cancer [3], congenital malformations [4-6], respiratory disease [7], and diabetes [8]. One of the chief limitations of the research to date concerns the lack of adequate characterization of human exposure, including limited knowledge of specific toxins at a given site, uncertainty about the route and intensity of exposure, and poor understanding of the toxicologic mechanisms of action. Although advanced methods such as pollutant dispersion modeling are promising, the bulk of the research focus has been, and continues to be, on simple methods based on distance, such as residential proximity to waste sites. This has led to considerable interest, concern, and controversy about the demographic characteristics of populations residing near hazardous waste sites [9, 10]. Presented here is a description of the population characteristics of communities located near hazardous waste sites in North Carolina.

By use of a geographic information system, NPL sites in North Carolina were located, and buffers of 1 and 4 miles were created around them. The buffers were then overlaid with census block group information. From this overlay, the percentage of the area in each block group was obtained, and the demographic variables were adjusted proportionally. The results are an area-weighted estimate of the population’s characteristics (Figure 1, available only in the online edition of the NCMJ). This method assumes that the population is evenly distributed throughout a block group. The 2010 Census Public Law File was used for the population estimates.

**FIGURE 1.**  
**National Priority List (NPL) Sites in North Carolina, May 2011**

This figure is available in its entirety in the  
online edition of the NCMJ.

Note: Data are from [11, 12] and the Environmental Protection Agency (unpublished).

**TABLE 1.**  
**Race/Ethnicity and Age of North Carolina Residents Living Within 1 and 4 Miles**  
**of a National Priority List Site**

Characteristic	Overall	≤1 mile	≤4 miles
Race/ethnicity			
1 race			
Any	9,329,284 (100)	79,423 (0.85)	953,766 (10.2)
White	6,528,950 (100)	51,029 (0.78)	643,273 (9.85)
African American	2,048,628 (100)	20,528 (1.00)	230,728 (11.3)
Native American	122,110 (100)	558 (0.46)	5,992 (4.91)
Asian	208,962 (100)	2,765 (1.32)	35,710 (17.1)
Pacific Islander	6,604 (100)	105 (1.59)	1,226 (18.6)
Other	414,030 (100)	4,385 (1.06)	36,778 (8.88)
Hispanic/Latino <sup>a</sup>	800,120 (100)	9,230 (1.15)	82,740 (10.3)
Age			
<18 years	2,281,635 (100)	20,764 (0.91)	228,763 (10.0)
≥18 years	7,253,848 (100)	61,212 (0.84)	752,450 (10.4)
Total	9,535,483 (100)	81,976 (0.86)	981,213 (10.3)

Note. Data are from [11] and indicate no. (%) of individuals living within the specified distance.  
<sup>a</sup>May include individuals in the categories above

Table 1 shows the race/ethnicity and age characteristics of individuals living within 1 mile and 4 miles of NPL sites in North Carolina. Less than 1% of North Carolina residents live within 1 mile of an NPL site, and approximately 10% live within 4 miles. Asian and Pacific Islanders composed the ethnic groups with the largest percentage of individuals living near NPL sites, whereas Native Americans composed the group with the smallest percentage. There was little difference among whites, African American, and Hispanics with respect to the percentage living near NPL sites. There was little difference in the age distribution of persons living near NPL sites; the percentages of persons younger than 18 years and 18 years or older who were living within 1 mile and 4 miles of an NPL were similar to those of the total population. Table 2 shows the proportion of North Carolina census block groups, stratified by income level, within 1 and 4 miles of an NPL site. There was no consistent trend in the relationship between income level and proximity to NPL sites.

Approximately 10% of North Carolina residents reside within 4 miles of a hazardous waste site listed on the NPL. Despite previous concerns that a disproportionate percentage of minorities and socioeconomically disadvantaged populations live near such sites, these findings suggest that residential proximity to NPL sites does not vary substantially by race/ethnicity or income level. The potential adverse health effects among persons residing near hazardous waste sites remains unclear, and effective evaluation of such risks presents a complex and expensive challenge. Given the current scarcity of resources, priorities might be better placed on site containment and remediation, rather than on continued health risk assessments of these potential public health hazards. NCMJ

**TABLE 2.**  
**US Census Block Groups (CBGs) Within 1 and 4 Miles of a National Priority List**  
**Site, by CBG Income Level**

Income	Overall	≤1 mile	≤4 miles
\$0-\$19,500	2,294 (100)	79 (3.44)	282 (12.3)
\$19,501-\$30,000	2,030 (100)	65 (3.20)	314 (15.5)
\$30,001-\$55,000	823 (100)	29/823 (3.52)	166 (20.2)
>\$55,000	119 (100)	0	17 (14.3)

Note. Data are from [12] and indicate no. (%) of CBGs within the specified distance.



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# North Carolina's Preparation for Gaining the Benefits and Meeting the Requirements of National Health Care Reform

Lanier M. Cansler

Passage and signing of the Affordable Care Act (ACA) have not ended the debate about the best way to guarantee access to affordable health care. While the debate continues, the responsibilities of US states to implement the provisions of the ACA remain a reality, pending congressional action or court decisions to the contrary.

Health care issues have been part of the national political debate since the presidential campaign of 1912, when President Theodore Roosevelt's Bull Moose Party included universal health insurance as part of its campaign platform. Presidents Franklin Roosevelt, Truman, Eisenhower, Kennedy, Johnson, Nixon, Carter, and Clinton have all preceded President Obama as participants in the national health care debate, examining options to assure access to affordable health care. It was on March 23, 2010, that President Obama signed the Affordable Care Act (ACA) into law. However, it is clear that the passage and signing of the ACA have not ended the debate about the best way to guarantee access to affordable health care. While the debate continues, the responsibilities of US states to implement the provisions of the ACA remain a reality, pending congressional action or court decisions to the contrary.

While the reach and the complexity of the ACA's more than 2,000 pages may make it difficult to fully understand, it is clear that much of the work to implement what many consider a transformative law will be the responsibility of the states and occur at the state level. North Carolina's ability to successfully implement the ACA—by taking advantage of the law's benefits by meeting the law's mandates—will require significant planning and effort. Most of the ACA's impact falls within 5 basic categories, each requiring planning and implementation efforts on the part of the state. The time frame for implementing the provisions of the ACA provides no opportunity to wait and see what might happen in Congress or the courts. North Carolina, along with most other states, has begun efforts to comply with the law.

The 5 basic categories of the ACA may be described as (1) health insurance reforms; (2) expansion of private insurance coverage via a high-risk pool or insurance exchanges;

(3) expansion of Medicaid coverage; (4) expansion of efforts and investment in prevention, wellness, safety net, and public health programs; and (5) longer-term opportunities for improvements in health care delivery and financing systems.

## Health Insurance Reforms

Most of the health insurance reforms were legislated to become effective within the first 6-9 months after the ACA's passage. The North Carolina Department of Insurance has done an outstanding job of enforcing these early reforms and, in doing so, has assured that North Carolina citizens are protected by, and benefit from, these changes.

## Expansion of Private Insurance Coverage

Expansion of private insurance coverage includes the immediate availability of guaranteed coverage for "previously uninsurable" individuals through the high-risk pool. The ACA calls for the establishment of health insurance exchanges by 2014 to offer private insurance products, coupled with premium subsidies, through tax credits, for individuals with incomes less than 400% of the federal poverty level. Also, a new payroll deduction option will be available for individuals who desire new low-cost limited coverage for long-term residential or in-home care services.

With the support of the governor and the commissioner of insurance, Inclusive Health, a preexisting, quasi-private entity authorized by the North Carolina General Assembly in 2005, successfully applied for federal funding to institute a new program of subsidized premiums for individuals who were previously considered uninsurable.

The federal law requires the establishment of a health insurance exchange in each state but provides states the option to develop the exchange themselves or allow the federal government to do so. The North Carolina Department

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Electronically published May 6, 2011.

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*N C Med J.* 2011;72(2):152-154. ©2011 by the North Carolina Institute of Medicine and The Duke Endowment. All rights reserved. 0029-2559/2011/72217

of Health and Human Services (DHHS) has worked closely with the North Carolina Department of Insurance and the North Carolina Institute of Medicine to apply for and receive federal grants to fund planning for the state's health insurance exchange. These early planning funds are being used to study options and prepare proposed authorizing legislation for the creation of an exchange in North Carolina, as well as to undertake initial developmental activities to ensure that the exchange is operational by the 2014 deadline. It is projected that the insurance products offered through the exchange, coupled with the premium subsidy for individuals with incomes less than 400% of the federal poverty level, will result in access to more-affordable health insurance for as many as 750,000 previously uninsured North Carolinians.

The DHHS Division of Aging and its constituent partners are eagerly awaiting federal guidance, expected this year, on the Community Living Assistance Services and Supports program, which will allow individuals to voluntarily set aside money from their paychecks for the costs of long-term-care coverage.

### **Expansion of Medicaid Coverage**

It is estimated that expansion of public coverage through the Medicaid program will provide health care coverage to an additional 530,000 North Carolinians, increasing the number covered under North Carolina Medicaid to more than 2 million individuals, or approximately 20% of the state's population. Beginning in 2014, all legal residents younger than 65 years whose income falls at or below 138% of the federal poverty level will be eligible for Medicaid coverage. Individuals who have incomes of more than 138% of the federal poverty level and are currently receiving Medicaid because of existing categorical eligibility will continue to have Medicaid coverage.

One key provision of the ACA is the requirement that states establish a "no wrong door" approach for individuals seeking to learn whether they are eligible or want to apply for a health insurance exchange product, NC Health Choice (North Carolina's Children's Health Insurance Program), or Medicaid. When this provision becomes operational, in 2014, individuals seeking to determine their eligibility and/or apply for coverage, as well as those who want to know their eligibility for a premium subsidy, will be able to do so at multiple locations, including the exchange, the DHHS, local departments of social service or public health offices, online, offices of many providers, and, hopefully, local libraries or the office of an insurance agent. This will be accomplished through technology that is being developed by the DHHS. Although the project began months ago, the DHHS has accelerated developmental work on North Carolina Families Accessing Services through Technology, a Web-based eligibility simplification and electronic eligibility determination system for 13 different income-related programs and services available through the department, including Medicaid, NC Health Choice, and now the health insurance exchange.

While the ACA requires the Medicaid and NC Health Choice electronic eligibility and enrollment system to be operational and integrated with the exchange programs by 2014, North Carolinians who apply for these programs will also be aware of and able to enroll in other income-related assistance programs offered through the DHHS. This system, which will include a statewide case management system for tracking all consumers and services, will result in improved access and service delivery for North Carolinians, while reducing administrative costs by an estimated hundreds of millions of dollars, at the state and local levels.

### **Expansion of Efforts and Investment in Prevention, Wellness, Safety Net, and Public Health Programs**

The ACA has provided funding for expansion of select public health, health promotion, and prevention programs. Led by its Division of Public Health, and working with traditional partners, the DHHS has pursued more than 2 dozen federal grants, resulting in \$14 million of new federal funds to support North Carolina programs in these areas.

### **Longer-Term Opportunities for Improvements in North Carolina's Health Care Delivery and Financing Systems**

It is in the area of health care financing and delivery system reform that North Carolina faces its greatest challenges, as well as its greatest opportunities. Simply put, the increasing trend in costs for public and private health care coverage in North Carolina cannot be sustained. As North Carolina's population grows (North Carolina is projected to be the seventh-most-populous state by 2030) and becomes older as the baby boomer generation ages, the cost of sustaining the Medicaid program will exceed the state's ability to pay for the program and meet other important obligations for education and public safety. The rate of increase in private premium costs is putting insurance coverage out of the reach of many North Carolinians, eroding employers' ability to assist in providing coverage, and contributing to increasing labor costs that make North Carolina businesses less competitive in a world market.

The ACA was not very prescriptive about what states should do in this area. It did set forth some planned changes for Medicare and suggested some promising areas that states or the private sector might explore. To this end, the DHHS is busy exploring new funding opportunities, new benefit designs, new approaches to health care provider reimbursement, improvements in care coordination, and new and more-cost-effective approaches to care delivery, which the ACA and the accompanying promise of more flexibility and a new spirit of collaboration by the Centers for Medicare and Medicaid Services provide.

To mention a few improvements, the DHHS and its Division of Medical Assistance will evaluate the option of establishing a "basic health plan" to assist persons likely to otherwise switch back and forth between the exchange

and Medicaid coverage. We will be examining new benefit designs for the individuals who will be newly eligible for Medicaid in 2014. We are working with Community Care of North Carolina to establish medical homes for Medicaid and NC Health Choice consumers, focusing not only on developing enhanced care management for individuals with chronic disease, but also on fully integrated care management that includes wellness, prevention, and mental health care services. This should not only lead to better care and health outcomes for covered individuals, it should also make the state's health care delivery system more cost-efficient and cost-effective, while potentially earning the state access to additional federal funding.

We are examining the opportunities, as well as the cost-associated benefits, of rebalancing and/or expanding coverage for home- and community-based services and preventive and diagnostic services for adults in the Medicaid program. We have undertaken an effort to improve intake processes at state psychiatric hospitals to capture other reimbursement opportunities and thereby save state tax dollars. The expansion of coverage inherent in the ACA should improve access to coverage and funding throughout the state's mental health services community.

In concert with the North Carolina Institute of Medicine and innovative providers, the DHHS will be exploring a variety of new delivery and financing mechanisms suggested in the ACA, including accountable care organizations, global payments, bundled payouts, and shared risks.

The ACA underscored and provided additional opportunity for 2 existing efforts at the DHHS. The first is Medicaid's movement away from payments for "never events," such as hospital-acquired infections, and its movement toward limiting reimbursement for avoidable hospital readmissions.

The second is a new and intensified effort to identify fraud and abuse in the delivery and consumption of health care services in North Carolina. Under Governor Bev Perdue's leadership, the DHHS has collaborated with 2 nationally recognized high-tech information technology and analytic companies to use sophisticated profiling and artificial intelligence to identify inappropriate reimbursements, such as those associated with fraudulent and suspicious claims, billing practices, billing patterns, and ownership patterns. Although this has already resulted in the identification of tens of millions of dollars in inappropriate Medicaid reimbursement expenditures, the technology is in its infancy, with substantial enhancements to be implemented in coming months that will further advance Medicaid's program integrity capabilities.

The ACA is expected to expand health care coverage to almost 1.3 million North Carolinians through either Medicaid or the health insurance exchange. The ACA has provided significant new dollars to expand public health and prevention programs. Without a doubt, the ACA is, and will be, visiting significant changes and challenges on nearly every sector of our health care delivery system. It certainly is imposing a lot of added work on the DHHS, its care partners, and our colleagues at the North Carolina Department of Insurance. Much has already been done, and a lot remains to be done in a very short time, to successfully implement health care reform in North Carolina. **NCMJ**

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#### **Acknowledgment**

Potential conflicts of interest. L.M.C. has no relevant conflicts of interest.

# Implementation of the Affordable Care Act in North Carolina

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**T**he Affordable Care Act (ACA) offers the potential to improve population health, health care access, and health care quality, while slowing the rate of increase in health care costs. But accomplishing these goals will not be easy. Implementing the new law creates challenges for North Carolina and the families, businesses, health professionals and organizations, and insurers in the state. Because of the complexities of the new law and its far-reaching consequences, the North Carolina Department of Insurance (DOI) and the North Carolina Department of Health and Human Services (DHHS) asked the North Carolina Institute of Medicine (NCIOM) to convene work groups to examine the new law and gather stakeholder input, to ensure that the decisions the state makes in implementing the ACA serve the best interests of the state as a whole. The effort is being led by the NCIOM Health Reform Overall Advisory Committee, cochaired by Lanier M. Cansler, CPA, secretary of the North Carolina DHHS, and Wayne Goodwin, JD, commissioner of the North Carolina DOI.

The advisory committee is helping to coordinate the efforts of 8 separate work groups that have focused on the following sections of the ACA: Medicaid; health benefits exchange (HBE) and insurance oversight; health professional workforce; prevention; quality; new models of care; safety net; and fraud, abuse, and overutilization. The work groups began meeting in August 2010 and have met approximately every month since. Altogether, 260 people from across the state are members of the advisory committee, work groups, or work group steering committees. Meetings are open to the public, and many individuals other than those in the advisory committee or work groups have participated in person or online. Financial support for this effort is provided by generous grants from the Kate B. Reynolds Charitable Trust, The Duke Endowment, the Blue Cross and Blue Shield of North Carolina Foundation, the John Rex Endowment, Cone Health Foundation, and the Reidsville Area Foundation. The North Carolina Network of Grantmakers has a Web site (available at: <http://www.ncgrantmakers.org>) that tracks new ACA grant announcements, to make it easier for North Carolina nonprofit agencies and other organizations to learn about funding opportunities related to the ACA. A copy of the interim report from the work groups is accessible on the NCIOM Web site (available at: <http://www.nciom.org/wp-content/uploads/2011/03/HR-Interim-Report.pdf>).

## Coverage Provisions

One of the primary reasons for passing the ACA was to make health insurance more accessible and affordable. In North Carolina, approximately 1.7 million nonelderly people (20.4% of the nonelderly population) were uninsured in 2009 [1]. The ACA builds on existing systems to expand coverage to uninsured individuals by extending Medicaid coverage to more low-income adults, strengthening the employer-based health insurance system, and making it easier and more affordable for many individuals and small businesses to purchase private coverage. According to the Congressional Budget Office, 92% of nonelderly people in the United States will have health insurance coverage by 2019 because of the ACA [2]. On the assumption that North Carolina will achieve a similar reduction in the number of uninsured people, more than 1.1 million uninsured North Carolinians are likely to gain coverage by 2019.

**Public insurance.** Beginning in 2014, the ACA will require states to expand Medicaid coverage to most uninsured adults who have a modified adjusted gross income of no greater than 138% of the federal poverty level (133%, plus a 5% income disregard allowed by the legislation); for a family of 4, the limit is equivalent to an annual household income of \$30,429 (ie, 138% x \$22,050). The federal government will pay an enhanced match rate for newly eligible individuals but not for those who would have been eligible under the state's Medicaid eligibility rules that were in effect in March 2010.

The North Carolina Division of Medical Assistance (DMA) estimates that the expansion of Medicaid will cover approximately 525,000 new people during state fiscal year (SFY) 2014, increasing to approximately 560,000 people overall by SFY 2019 (S. Owen, chief business operating officer, North Carolina DMA, electronic communication, February 22, 2011). North Carolina's share of the coverage during SFYs 2014-2019 for new enrollees is estimated to be

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Electronically published May 20, 2011.

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**NC Med J. 2011;72(2):155-159.** ©2011 by the North Carolina Institute of Medicine and The Duke Endowment. All rights reserved. 0029-2559/2011/72218

approximately \$830 million, and the federal share is estimated to be more than \$15 billion. North Carolina is likely to incur additional costs in operating new eligibility and enrollment systems to ensure that individuals can apply simultaneously for Medicaid, NC Health Choice (ie, North Carolina's Children's Health Insurance Program), and private, subsidized coverage offered through the HBE. North Carolina may also incur new costs if it chooses to expand the array of services offered. However, there are also ways for the state to offset some of the new costs it will likely incur from the expanded coverage. For example, as uninsured individuals acquire public or private coverage, the state may be able to reduce costs in other programs that served these individuals while they lacked coverage. It is difficult to quantify the full financial impact of the ACA on North Carolina until the state has a better understanding of the required benefit package for newly eligible individuals, as well as federal guidance on the new service options and enhanced match rates. Thus, the North Carolina DHHS will continue to work to estimate the potential costs and cost offsets as further federal guidance becomes available.

**Individual and employer-sponsored private insurance.** Most of the other coverage changes occur in the private insurance market. The more immediate provisions focus on making coverage more affordable for people with preexisting conditions and for early retirees. The ACA appropriated \$5 billion over federal fiscal years (FFYs) 2010-2014 to create federally funded high-risk pools to provide more-affordable coverage to people with preexisting health problems who have been uninsured for at least 6 months. In North Carolina, the federally funded high-risk pool is being operated by Inclusive Health. North Carolina's share of this \$5 billion appropriation was \$145 million. In addition, the ACA appropriated \$5 billion over FFYs 2010-2015 to create a temporary reinsurance pool to help offset the high claims costs to businesses (including state and local governments) that provide health insurance to early retirees aged 55 years or older who are not eligible for Medicare. As of January 27, 2011, a total of 101 North Carolina employer groups—including the State Health Plan, 28 counties, 20 North Carolina towns and cities, and other businesses and organizations—met the eligibility requirements for reinsurance to offset part of the claims costs for early retirees [3]. The State Health Plan estimates that it will receive \$22.7 million in SFY 2011, \$57.9 million in SFY 2012, and \$8.9 million in SFY 2013 from the federal reinsurance pool (M. Moon, chief financial officer, North Carolina State Health Plan, electronic communication, January 18, 2011).

The ACA also made changes to insurance laws that became effective for health plans renewed after September 23, 2010. For example, insurers are now required to offer parents the option of continuing insurance coverage for children up to 26 years of age, regardless of whether the children are full-time students. Insurers are also prohibited from imposing lifetime dollar limits for coverage, and the law begins to

phase out annual limits. Insurers that offer child-only coverage are also prohibited from excluding children with preexisting conditions. There are also new requirements to ensure that insurers spend at least a minimum amount of the premiums they collect on medical expenses and quality improvement, rather than spending them on administrative costs or retaining them as profits.

The ACA includes enhanced consumer protections, including the creation of consumer ombudsman programs. The North Carolina DOI obtained federal grants of \$1 million, to strengthen the rate-review process, and \$850,000, to strengthen its consumer-assistance/ombudsman program. In addition, the North Carolina DOI Seniors' Health Insurance Information Program, the Area Agencies on Aging, and the Community Resource Connections for Aging and Disabilities received a combined amount of \$1,752,034 to expand outreach efforts and enroll qualifying Medicare beneficiaries in the low-income prescription drug subsidy program and/or the Medicare Savings Program.

Most of the other changes to insurance law go into effect in 2014. The secretary of the US DHHS will define the essential benefits that private insurers must cover in their nongrandfathered insurance plans. Over time, most people in the private market will be covered by the essential health benefits. Beginning in 2014, insurers can no longer exclude people or charge them more because of preexisting conditions. To ensure a large enough pool of individuals to cover the higher costs of insuring individuals with preexisting health conditions, the ACA requires most people to have health insurance coverage or pay a financial penalty. The ACA provides subsidies to individuals to help make insurance coverage more affordable. People are eligible for these subsidies if their annual income is less than 400% of the federal poverty level (eg, \$88,200 for a family of 4 in 2010), if they are not eligible for public coverage (eg, Medicare, Medicaid, NC Health Choice, or TRICARE) and if they do not have access to affordable employer-sponsored insurance. Analysis of Current Population Survey data suggests that close to 800,000 uninsured nonelderly people have incomes that are too high to qualify for Medicaid or NC Health Choice but are less than 400% of the federal poverty level (M. Holmes, Cecil G. Sheps Center for Health Services Research, unpublished analysis, 2011). Some, but not all, of these individuals will be eligible for a subsidy to purchase coverage in the HBE [4, 5]. Others may gain coverage through their employers.

Beginning in 2014, the ACA also requires large employers (ie, businesses with 50 or more full-time employees) to offer health insurance coverage that meets certain standards or pay financial penalties. Almost all (97%) of these firms already offer coverage in North Carolina [6]. In contrast, only 33.8% of small businesses (ie, businesses with fewer than 50 full-time employees) offer group health insurance coverage. Small businesses are not required by the ACA to offer health insurance coverage. However, the ACA provides

a sliding-scale tax credit to some small businesses to help them afford coverage. On the basis of Current Population Survey data [4] (M. Holmes, unpublished analysis, 2011), Medical Expenditure Panel Survey data [7], and the assumption that all firms qualifying for the partial credit would receive a 17.5% tax credit, the NCIOM estimates that small businesses in North Carolina may be able to qualify for more than \$200 million in tax credits through the small-business tax credit.

The ACA requires each state to have an HBE that offers information to help individuals and businesses compare health plans on the basis of quality, provider networks, and costs and that helps individuals and small businesses enroll in coverage. If a state chooses not to create its own HBE, the federal government will create one to offer coverage to individuals and small groups in the state. The Health Reform Overall Advisory Committee and Health Benefits Exchange and Insurance Oversight Workgroup recommended that North Carolina create its own HBE, which would give the state greater control over its operations. The North Carolina DOI received a \$1 million planning grant from the federal government to help with some of the design issues. Currently, the North Carolina General Assembly is considering legislation to create a North Carolina HBE. Federal funds are available to cover the developmental costs for any state that decides to create its own HBE.

### Improving Population Health

Ultimately, the goal of any broad-scale reform of the health system should be to improve population health. The ACA includes new funding to invest in wellness and public health infrastructure. This focus on improving population health is particularly important to North Carolina. The state typically ranks among the bottom third of all states for most health status indicators, and in 2010 North Carolina ranked 35th in overall health [8].

The ACA appropriated \$500 million in FFY 2010 and \$750 million in FFY 2011 for a new prevention and public health fund to help fund new prevention efforts and to fund grants to strengthen the public health infrastructure. The North Carolina Division of Public Health and local health departments applied for and were awarded approximately \$11.6 million in ACA grants aimed at strengthening the public health infrastructure and improving population health.

### Increasing Access to Health Services

To meet the health care needs of newly insured individuals, the ACA authorized new workforce programs and appropriated funding to strengthen the health care safety net.

**Expanding the health professional workforce.** The ACA expanded or authorized new health professional training programs to increase the number of primary care professionals, nurses, public health professionals, allied health professionals, mental health and substance abuse professionals, dental health professionals, and direct-care work-

ers. In addition, the legislation aimed to change the way that health professionals are trained, to best meet the workforce needs of the future. However, although the ACA authorized many new training programs, Congress did not appropriate new funding to support all of them. As a result, in FFY 2010, the US DHHS secretary used approximately half of the prevention and public health fund to support workforce training programs for health professionals.

State agencies and academic institutions in North Carolina have successfully competed for more than \$9.5 million in ACA workforce awards. For example, the University of North Carolina (UNC)-Chapel Hill School of Medicine received funding to expand its pediatrics residency program, and the New Hanover Regional Medical Center and South East Area Health Education Centers received funding to expand their family medicine residency program; the Duke University School of Medicine and Methodist University received funding to expand their physician assistant programs; the Duke University School of Nursing received funding to expand its nurse practitioner program; the UNC-Chapel Hill Gillings School of Global Public Health received funding to expand its public health workforce; the North Carolina Commission on Workforce Development and the UNC-Chapel Hill Cecil G. Sheps Center for Health Services Research received funding to identify strategies the state can employ to increase the per capita primary care workforce during the next 10 years; and the North Carolina DHHS Office of Long-Term Services and Supports received funding to improve training for personal and home care aides.

Although the ACA does not include new appropriations for most of the new workforce training programs, it does include \$1.5 billion in new funding, distributed over 5 years, to expand the National Health Service Corps. The North Carolina Office of Rural Health and Community Care, which is the lead agency in administering the National Health Service Corps in North Carolina, estimates that the state will be able to use these funds to recruit an additional 20-25 health professionals per year during 2011-2015 to practice in underserved areas (J. Price, director, North Carolina Office of Rural Health and Community Care, electronic personal communication, January 27, 2011).

**Expanding the safety net.** The ACA includes provisions to increase and strengthen the health care safety net. The ACA appropriated a total of \$9.5 billion, distributed over 5 years, to expand the number of community and migrant health centers, expand the array of services provided, and increase the number of people served. In addition, the ACA includes \$1.5 billion for construction and renovation. North Carolina currently has 26 federally qualified health centers (FQHCs) and 2 FQHC look-alikes operating in 45 counties across the state.

North Carolina FQHCs received ACA grant funds totaling \$19.2 million to support capital improvements and renovations and to expand access to care through existing FQHCs. In addition, the Health Resources and Services Administration

issued a grant opportunity to support the establishment of new service delivery sites for FQHCs. The North Carolina Community Health Center Association, with financial support from the Kate B. Reynolds Charitable Trust, worked with communities across the state to help them prepare grant applications. As a result, North Carolina submitted 30 applications for competitive New Access Point grants. If all of these applications were selected for funding, the grants would fund services in 24 new counties, bringing the total number of North Carolina counties with an FQHC up to 69. However, the recent FFY 2011 budget reconciliation agreement reduced core FQHC funding by approximately \$600 million. This effectively reduced funding for New Access Points by approximately two-thirds. Thus, it is unlikely that all of the New Access Point grants will be funded (B. Money, North Carolina Community Health Center Association, personal communication, May 2, 2011).

In addition to the direct funding for FQHCs, the ACA includes new requirements for charitable hospitals to maintain their tax-exempt status. Under the new provisions, charitable hospitals must conduct a community needs assessment and identify an implementation strategy to show that they are addressing community needs. Nonprofit hospitals are also required to have a financial assistance policy, provide emergency services, and limit charges to people eligible for assistance to the amounts generally billed.

### **Enhancing Quality and Reducing Health Care Costs**

North Carolina has many existing initiatives aimed at improving health care quality while reducing health care costs, yet more work is needed.

**Quality.** The ACA includes many provisions aimed at measuring and reporting on the quality of care provided by health professionals, health care organizations, and insurers. Over time, these data will be made available to the public. In addition, the ACA provides greater investments in comparative effectiveness research to determine which treatments, medications, or services work best under which conditions. The ACA also begins to change the way that health professionals and providers are reimbursed, from a system based largely on reimbursing providers on the basis of the volume of services provided to systems that are based, in part, on the quality and outcomes achieved.

North Carolina had already begun several initiatives aimed at improving quality of care before the enactment of the ACA, including but not limited to Community Care of North Carolina (CCNC), the North Carolina Healthcare Quality Alliance, the Regional Extension Center, Improving Performance in Practice, the North Carolina Center for Hospital Quality and Patient Safety, and the North Carolina Center for Public Health Quality. Representatives from these organizations, along with representatives from other health care provider groups, served on the NCIOM Quality Workgroup. The ACA has many requirements to improve quality and patient safety. For example, beginning

in October 2012, Medicare will reduce payments to hospitals that have excess readmissions for 3 conditions: heart attack, heart failure, and pneumonia. Stakeholder groups have been identified to educate providers about the new requirements. Furthermore, many of the existing statewide quality improvement organizations are working with providers to help them implement quality improvement strategies to meet these new requirements.

**New models of care.** The ACA includes many new provisions aimed at changing the way that Medicare, Medicaid, and NC Health Choice deliver care and pay health professionals and other health care organizations for services. The intent of these provisions is to test models to increase quality and reduce unnecessary costs. The secretary of the US DHHS is charged with evaluating these demonstrations, identifying successful initiatives, and disseminating the successful financing and delivery models more widely throughout the country.

Development and implementation of new models of care are essential to improve the value delivered by the US health care system. North Carolina is already recognized for the work it has done through CCNC to create patient-centered medical homes in the Medicaid program. CCNC helps improve health outcomes and reduce health care costs, particularly for Medicaid enrollees with chronic or complex health problems. Because of the success already achieved with CCNC, North Carolina was among 8 states selected to receive the first round of demonstration grants awarded through the Center for Medicare and Medicaid Innovations (also known as “the Innovation Center”) to test a multipayer, advanced, patient-centered medical home [9]. Under this grant, Medicare will pay an estimated \$11.8 million in per-member per-month payments to local primary care providers and participating CCNC networks to provide care coordination and care management to Medicare enrollees. This is part of a larger public-private partnership that includes the North Carolina DMA, the State Health Plan, Blue Cross Blue Shield of North Carolina, and North Carolina Community Care Networks.

North Carolina also received 2 grants to test or expand existing initiatives to improve quality and health outcomes. Roanoke Chowan Community Health Center received \$255,000 through the ACA to expand its existing telehealth monitoring initiative. Access II Care (which serves Buncombe, Henderson, and McDowell counties in North Carolina) and the North Carolina Office of Rural Health and Community Care received a medical liability reform and patient safety planning grant of \$297,710 from the Agency for Healthcare Research and Quality to develop a system of near-miss reporting and improvement tracking in primary care.

**Fraud, abuse, and overutilization.** The ACA includes funding to support more-aggressive efforts to eliminate fraud and abuse and to recover overpayments in Medicare, Medicaid, and CHIP. These new efforts are expected to yield \$6 billion



in savings to the federal government during the next 10 years (and a corresponding reduction in costs to states' Medicaid and CHIP programs). Many of these efforts will require North Carolina to implement new surveillance and enforcement procedures and to educate health care providers about the new provisions.

## Conclusion

The ACA is complex and touches all aspects of the US health care system. Not surprisingly, the legislation has been controversial. Any legislation that impacts 17% of the economy and affects how health care services are delivered and financed is likely to be controversial. Some argue that the bill does not go far enough toward ensuring universal coverage, while others decry the lack of real cost containment. Some oppose the individual mandate, while others are concerned about the new requirements placed on employers and state government. Yet few people seriously argue that the existing health care system is sustainable. The United States spends more per capita on health care than any other country, yet these costs yield less value in terms of life expectancy and other important measures of health. The country spends enormous sums of money on new technology and better "sick care" but does not make the investments in prevention that could help keep people healthy. Providers continue to be paid on the basis of the volume of services provided, without ensuring the quality of these services. Furthermore, millions of people remain uninsured, which has an adverse impact on individuals, families, and society.

The ACA is not perfect and is likely to evolve as we learn what works and what needs to be changed. However, it provides North Carolina with a unique opportunity to identify strategies to expand health insurance coverage and improve access to health services, quality, and population health. North Carolina has a strong history of identifying innovations that have led to improved access, quality, and patient outcomes, as well as to reductions in unnecessary health expenditures. However, there is a need for further progress. Working together, North Carolina health professionals, consumers, insurers, and business and community leaders can identify innovative strategies that will lead to further improvements in quality, outcomes, and population health; improved access; increased efficiency; and reduced costs. **NCMJ**

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## Acknowledgments

We thank Mark Holmes for analysis of Current Population Survey data.

Potential conflicts of interest. All authors have no relevant conflicts of interest.

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# The National Children's Study in North Carolina: A Study of the Effect of the Environment on Children's Health, Growth, and Development

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The National Children's Study, a longitudinal cohort study exploring relationships among broadly defined environmental exposures and children's health, is assessing whether these exposures are harmful, harmless, or helpful. The study is presently underway in 37 locations (2 of which are in North Carolina) and will expand to enroll 100,000 children across the United States.

The National Children's Study (NCS) is the largest study of children's health ever to be conducted in the United States. The study plans to enroll 100,000 children, with 7,000 slated to come from North Carolina. Children and their families will be followed prospectively from the prenatal period until the children reach 21 years of age, to investigate the influence of environmental factors on child health, growth, and development. The NCS defines "environment" very broadly, to include the air children breathe, the water and food they consume, the noises they hear, their behaviors, and the families and neighborhoods in which they live. In addition, the study will examine the interplay between environmental influences and genetics and its effects on child health. Ultimately, information learned by means of the NCS will form the basis for future guidance on child health care, including treatments and policies toward improving child health.

Recruitment for the NCS was launched in January 2009 at 2 study locations, one of which was Duplin County, North Carolina; the other was Queens, New York. Three months later, recruitment started at 5 more locations across the country. An additional 30 locations, including Durham County, North Carolina, commenced enrollment in late 2010 and early 2011. As there are 2 active study sites in North Carolina, with the potential for expansion to another 5 North Carolina communities, the statewide medical community needs to be knowledgeable about this important child health study. The purpose of this article is to promote awareness of the NCS among health care professionals in North Carolina. Because North Carolina clinicians are a trusted source of information and guidance about health issues, it is hoped that they will encourage participation of potentially eligible and enrolled study subjects.

To supplement the information about the NCS provided in this brief overview, readers can access the national study Web site (available at: <http://www.nationalchildrensstudy.gov>). Information about the Duplin and Durham County locations can be accessed at their respective Web sites (<https://centers.nationalchildrensstudy.gov/unc/locations/duplin/> and <https://centers.nationalchildrensstudy.gov/unc/locations/durham/>).

## Study Rationale

Child health advocates recognize that there are numerous pressing child health concerns that have recently increased in prevalence, nationally and in North Carolina. Among the health-related conditions to be addressed by the study are preterm births, childhood asthma, and obesity. In particular, the percentage of preterm births in the United States, defined as children born at fewer than 37 weeks of completed gestation, climbed steadily, from 11.4% in 1997 to 12.8% in 2006. In the United States, during 2007, approximately 1 in 8 babies (12.7%) was born preterm, and approximately 1 in 12 babies (8.2%) had a low birth weight [1]. Simultaneously, in North Carolina, the percentages of preterm and low-birth-weight children were higher than those reported nationally, at 13.3% and 9.2%, respectively. Racial disparities persist across the United States and in North Carolina, without an understanding of why. Between 1980 and 1996, the period prevalence of asthma also increased, so that by 2007, 9.1% of US children (6.7 million) had asthma [2]. Furthermore, since 1980, the prevalence of childhood obesity has tripled among US school-aged children and adolescents, and it remains high, at approximately 20% [3]. In 2007, more than 33.5% of North Carolina children aged 10-17 years were overweight or obese, outpacing the national prevalence of 31.6% [4]. These health trends for children in North Carolina and the United States are of concern and demand further study.

Electronically published May 20, 2011.

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Recognition of the magnitude of these critical child health concerns and the fact that the last large-scale, longitudinal study of child health in the United States was conducted more than 50 years ago prompted allocation of federal funding for a more contemporary children's health study. Findings from the earlier Collaborative Perinatal Project (CPP), which included more than 40,000 children, provided the basis for insights into such child health problems as cerebral palsy, febrile convulsions, neonatal jaundice, and congenital rubella [5]. Since the conclusion of the CPP, numerous factors have changed in the lives of American children. With the rapid advent of novel chemicals, materials, and medications, the potential for exposures of children to potentially harmful substances has increased over time [6]. Compared with children in earlier periods, a significant proportion of today's young children spend large amounts of time outside their home environments, in organized child care facilities or more-informal care settings with relatives, family day care providers, or nonrelatives [7]. Moreover, recent advances in science and technology, such as knowledge of the human genome, allow for the potential of improved understanding and measurements of child health conditions, when compared with earlier times. With the Children's Health Act of 2000 [8], the US Congress authorized the NCS, and funding for study implementation was subsequently allocated in 2007.

### Study Design

NCS child participants are intended to come from more than 105 US locations, known as primary sampling units (PSUs). It is anticipated that the study will recruit at least 100,000 participants. PSUs, which largely correspond to counties, were chosen at random but in such a way that the population of study children would be geographically, racially, and ethnically representative of children residing in the United States [9]. On the basis of census blocks, the PSUs are further subdivided into secondary sampling units (SSUs) with an equal number of births. For very sparsely populated locations, SSUs are large in area and fewer in number. Conversely, for densely populated areas, there are a large number of SSUs that are smaller in area—in fact, in some regions, they may be a single apartment building or complex. Approximately 10-15 SSUs are selected at random in each study location so that, ultimately, 1,000 children will be recruited in that location during a 4-year period. This means that only women residing within selected SSUs at each study location are eligible to join the study. This national probability sampling strategy was chosen to introduce the least amount of bias into participant selection.

Seven of the initially proposed 105 NCS locations are in North Carolina. Besides Duplin County and Durham County, it is anticipated that 5 additional North Carolina counties will be included: Buncombe, Burke, Cumberland, Gaston, and Rockingham. This could result in approximately 7,000 (7%) of the children in NCS coming from North Carolina (Figure

**FIGURE 1.**  
North Carolina Counties Selected for Participation in the National Children's Study



1). Consequently, children and families from North Carolina are making significant contributions to, and will continue to play an important role in, the NCS.

Women between the ages of 18 and 49 years who are either pregnant or planning to become pregnant and who also reside within the selected areas of each study location are invited to enroll in the study. Assenting pregnant women younger than 18 years may participate with parental consent. After birth, children become study participants. Fathers are also invited to participate. Written informed consent and written informed assent, when age appropriate, are obtained from all study participants.

### Participant Recruitment

The NCS has 2 major components: the vanguard study and the main study. The vanguard study, which started in 2009, is meant to inform the design of the main study. After the launch of the main study in 2012, the 2 studies will move forward in parallel, with the vanguard component always informing the design of the main study. Participation in the vanguard experience, therefore, is critical to the success of the NCS.

The vanguard study was initially designed to include the first approximately 1,750 children enrolled in the NCS. In the initial 7 vanguard NCS study locations, which include Duplin County, women were recruited into the study through a number of different methods. The primary strategy used "household-based" recruitment. Much as in the census, field staff went door-to-door in the selected areas in the study location. The number of potentially age-eligible women residing in each dwelling unit was enumerated, and a pregnancy screening survey was administered to women who agreed to be screened, to determine whether they were pregnant or likely to become pregnant. Eligible women were then invited to participate. Supplemental recruitment occurred through referral to the study by medical care providers or via self-referral.

By September 2010, approximately 1,400 women had been enrolled in the NCS across the initial 7 vanguard locations and had given birth to approximately 600 children [10]. To date, more than 110 births to women enrolled in the NCS have occurred in Duplin County. Although 63% of

potentially eligible women consented to participate, rates of recruitment into the study at the initial 7 vanguard sites were lower than the original target. During this initial vanguard phase, it became apparent that determination of the most-efficient methods for recruitment into a study of this magnitude requires further exploration.

The 30 newly expanded NCS vanguard locations are evaluating 3 alternate recruitment strategies at 10 locations each. One strategy will use lessons learned and best practices from the initial vanguard experience and adapt them to evaluate an “enhanced household recruitment” model. A second, “2-tiered high-intensity/low-intensity” strategy will recruit women from a broader geographic area than those of the selected SSUs in a study with a lower-intensity design, from which a subset of geographically defined women and children will be selected for participation in a more intensive study protocol. The third, “provider-based” recruitment strategy will primarily recruit eligible women by working with prenatal and other health care professionals. Each of these strategies is designed with the goal of identifying the most-efficient methods for recruiting study-eligible women in the selected SSUs. In Durham County, the “provider-based” strategy is being implemented. Recruitment in Durham County started in January 2011, and a number of births to enrolled women have already occurred. Ultimately, it may be learned that different recruitment strategies or combinations of strategies will work better in different study locations. Currently, it is estimated that the second phase of the vanguard component of the study will enroll approximately 3,000 children.

## Study Procedures

During the initial vanguard phase, NCS data collection included a prepregnancy study visit for women planning to become pregnant; for those already pregnant, data collection included a study visit during each pregnancy trimester. In Duplin County, with the exception of prenatal ultrasonography performed during each trimester, prenatal study visits occurred in the home. In addition to prenatal ultrasonography, data collection during pregnancy included environmental samples (ie, air, water, and dust samples from the home), maternal physical measurements (ie, anthropometric data and blood pressure), maternal biospecimens (ie, blood, buccal swab specimens, hair samples, saliva, urine, vaginal swab specimens, and nail clippings), questionnaire response (ie, social, behavioral, dietary, and demographic information, as well as medical history), and diaries. Measurements and specimens obtained from fathers included anthropometric data, blood pressure, buccal swab specimens, hair samples, nail clippings, and questionnaire responses.

Study visits also occurred at the birthing hospitals, just after delivery. Study measurements and biospecimens obtained at the birthing hospitals included maternal blood samples obtained before delivery, umbilical cord blood, umbilical cord and placenta, infant capillary blood specimens

(coordinated so as to be obtained at the same time blood is obtained for routine newborn screening), infant meconium samples, infant measurements (ie, length, weight, head circumference, and skin-fold thickness), a brief dysmorphic assessment, and infant photographs. Prenatal, delivery, and newborn medical records were abstracted. During the first year of the child’s life, there are 4 scheduled study visits (ie, 2 in-home and 2 telephone-based interviews), to assess the health, growth, and development of the child, along with ongoing environmental exposures. To synchronize the protocols across the 37 study locations, some of these protocols are currently being revamped as the 30 new sites begin data collection. Continued assessments not yet developed will occur until children reach 21 years of age.

The biological and environmental samples and health measurements obtained as part of the NCS will serve as a rich repository of specimens and data with which to answer both current and future questions about the effects of the environment on child health. On the basis of the work performed during the initial vanguard component, the precise measurements to be included in the main component of the NCS will be determined. Given that this is a longitudinal study during which children will be followed for 21 years, assessments may change and evolve over time.

## Engaging the Community and Medical Providers

A challenging part of conducting the NCS is becoming familiar with the study locations, which present diverse demographic profiles, cultures, and traditions. Obtaining input from community members is a necessary and critical component of the NCS in every study location. To facilitate this process, each study location is required to have a community advisory group (CAG) to inform the local study process. CAGs can inform the study team on how best to do outreach to their own communities and engage study participants. For example, in Duplin County, the CAG advises the study team about the best methods of promoting and advertising the NCS in Duplin County, important community events at which to have a presence, and appropriate incentives for study participation. The CAGs have also offered suggestions for working with difficult-to-reach populations in the community. At the invitation of study staff, CAG members have been asked to volunteer their time and expertise. CAGs are composed of diverse groups of individuals from the study county, including but not limited to health care professionals, child advocates, community leaders, education professionals, industry representatives, leaders in the faith community, and parents. Because the NCS will work in these communities for a long time, CAG members will serve for a limited time, presenting opportunities for other members of the community to serve. Outreach to a broad range of community stakeholders also takes place, and it provides an opportunity for many to offer their suggestions to the study team.

Engaging health care professionals in each study commu-

nity is essential to the success of the NCS protocol. Because the study is conducting visits at birthing hospitals, building relationships with the hospitals, the staff in those hospitals, and the clinicians is critical. The study team relies heavily on the support of the staff in the birthing hospitals to assist with the collection of biospecimens, such as umbilical cord blood. Furthermore, obstetrical care professionals can assist by publicizing the study to their patients, by understanding the importance of the study for their patients and the community, and by supporting the decisions of their patients to join the study [11]. In Durham County, where women are being recruited in the prenatal care clinicians' practices, building relationships with the health care professionals is imperative. The ability to build good study team and clinician communication will determine the ultimate success of any recruitment strategies that use a "provider-based" recruitment component. The NCS medical outreach staff for Durham County have invested a significant amount of time learning about each of the obstetrical practices serving county residents. It is the goal of the study team to work with the practices so that study recruitment does not interfere in any way with daily medical office operations.

### Future Study Directions

As previously noted, the NCS started actively recruiting at the initial 7 vanguard sites in January 2009, and recruitment efforts at 30 expanded vanguard locations got underway in late 2010 and early 2011. Data from participants recruited during the vanguard phase are currently being analyzed and will be used to inform the conduct of the full study, which is slated to start recruitment in 2012.

A particular challenge for the NCS will be participant retention for a 21-year-long study, given today's highly mobile population. Mechanisms for referring study participants who move long distances to other nearby study centers will be explored. When participants move to locations far from an NCS study center, alternate methods for follow-up will be considered, such as telephone contacts and self-collected specimens.

The NCS study centers are also currently engaged in formative research projects meant to guide the conduct of the main study. Many of the projects are focused on evaluating innovative approaches to assess cognition, genetics, and environmental exposures. Environmental exposures of particular interest include air and water quality and exposures to pesticides, semivolatile organic compounds, phthalates, polybrominated diphenyl ethers (organobromine compounds that are used as flame retardants), and bisphenol A (an organic compound used to make polycarbonate plastic and epoxy resins). Locally, the North Carolina study center is spearheading several formative research projects. One project is designed to assist with linking data from the NCS to data from statewide immunization information systems, such as the North Carolina Immunization Registry. Another local project is evaluating ways to improve dietary assess-

ments of NCS participants. In Duplin County, a project led by the North Carolina team is studying neighborhood effects on children's health by conducting a systematic observation of the characteristics of the communities where NCS children live, to assess their influence on children's health. This approach may be expanded to other study locations.

### NCS Contributors

On a national level, the primary agency leading the NCS is the Eunice Kennedy Shriver National Institute of Child Health and Human Development of the National Institutes of Health. Other federal study partners include the National Institute of Environmental Health Sciences of the National Institutes of Health, the Centers for Disease Control and Prevention, and the Environmental Protection Agency. In North Carolina, the study is managed by the Carolina Population Center at the University of North Carolina–Chapel Hill, in partnership with Duke University, Battelle Memorial Institute, and McMillan & Moss Research. The local study team is composed of a diverse group of professionals, including social scientists, obstetricians, pediatricians, and public health researchers. The NCS has been reviewed by multiple institutional review boards at federal and local levels, and the study plan was reviewed in 2008 by the National Academy of Sciences [12].

### Summary

The NCS is a dynamic study assessing the effect of the environment on children's health, growth, and development. Through longitudinal assessments of children from across the United States, including a large number of children from North Carolina, the study will gain insights into many childhood health problems, to better assist both clinicians and policymakers with planning for the health care of America's future generations. **NCMJ**

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### Acknowledgments

The views expressed in this article are the responsibility of the authors and do not necessarily represent the position of the National Children's Study, the National Institutes of Health, or the Department of Health and Human Services.

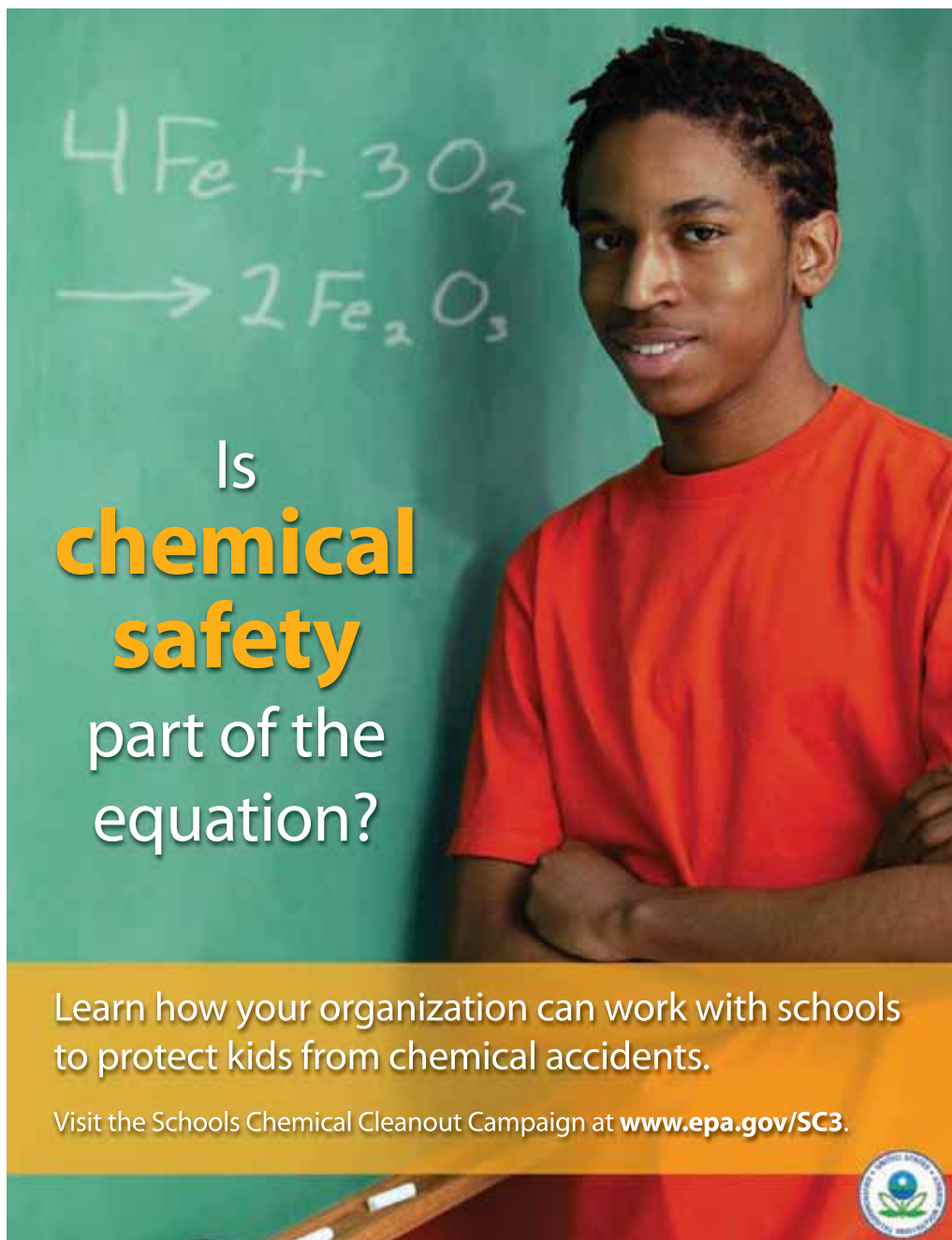
Financial support. Eunice Kennedy Shriver National Institute of Child Health and Human Development (grants HHSN275000503413C, HHSN267200700049C, and HHSN275200800029C).

Potential conflicts of interest. All authors have no relevant conflicts of interest.

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