Using Geographic Information Systems to Assess Risk for Elevated Blood Lead Levels in Children

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SYNOPSIS

Objectives. Targeted screening for childhood lead poisoning depends on assessment of risk factors including housing age. Using a geographic information system (GIS), we aim to determine high-risk regions in Charleston County, South Carolina, to assist public health officials in developing targeted lead-screening.

Methods. Properties built before 1978 were geocoded (assigned latitude and longitude coordinates) from tax assessor data. Addresses of Charleston County children who have been screened for lead poisoning were also geocoded. Locations of all housing, lead poisoning cases, and negative screens were created as separate map layers. Prevalence ratios of lead poisoning cases were calculated, as were relative risks for each category of housing.

Results. Maps of Charleston County were produced showing the location of old housing, where screening took place, and where cases were found. One thousand forty-four cases were identified. Twenty percent of children living in pre-1950 homes had elevated blood lead levels (EBLL). Children living in pre-1950 housing were 3.9 times more likely to have an EBLL than children living in post-1977 housing. There was no difference in risk of living in a 1950–1977 home vs. a post-1977 home. A large number of cases were also found in an area of newer houses, but near a potential point source. Eighty-two percent of all screens were from children in post-1977 homes.

Conclusions. Children living in pre-1950 housing were at higher risk for lead poisoning. GIS is useful in identifying areas of risk and unexpected clustering from potential point sources and may be useful for public health officials in developing targeted screening programs.

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The prevalence of childhood lead poisoning in the United States has decreased since the mid-1980s.[1,2] The Centers for Disease Control and Prevention (CDC) attributes most of this decline to the removal of lead from gasoline and soldered cans.[2] In addition, the 1978 Consumer Product Safety Commission banned the use of lead-based paint on residential surfaces and toys, so that all houses built since 1978 should contain no lead-based paint.[3] Unfortunately, the problem of childhood lead poisoning has not been eliminated, but instead has remained a serious public health problem concentrated in high-risk populations. Higher prevalence of lead poisoning has occurred among children of lower socioeconomic status and among racial/ethnic minorities. In addition, a higher prevalence of lead poisoning has been documented in children living in housing built before 1950 compared to children living in newer housing. The mean blood lead level is also higher for these same children.[1,4,5] The release of these data has prompted the CDC to recommend major changes in lead-screening, placing emphasis on a targeted screening approach,[6] rather than the universal screening recommendation of 1991.[3] State public health departments were charged by the CDC to develop screening plans for their state.[6]

Under the targeted screening plan, only areas designated as "high-risk" would conduct universal screening. Population-based lead prevalence data for a corresponding geographic region is the preferred method to designate an area as high-risk, and therefore require universal screening of all one- and two-year-olds. Recognizing that these data were non-existent in many communities, the CDC provided interim recommendations for targeted screening until prevalence data became available. These suggest screening all children in counties in which ≥27% of the houses were built before 1950, and screening all children who receive Medicaid, as a proxy for poverty.[6]

Targeted screening for childhood lead poisoning requires an assessment of risk, including age of housing. Many clinicians assess age of housing by asking parents. Unfortunately, uncertainty exists about the parents' ability to reliably determine age of housing. In our population, asking parents whether they lived in a house built before 1950 was not reliable and could not be used for risk assessment.[7] Reliance on census data may also be problematic, as census data rely on respondent's estimates. Evidence indicates that there is under-reporting in the older structure categories.[8]

We have developed a geographic information system (GIS) that enhances the reliability of determining housing age, particularly among families who rent their homes. GIS may also be an ideal mechanism to identify clustering of cases based on an isolated exposure source. This method was hypothesized to have a greater case finding rate than door-to-door screening,[9] and has been demonstrated to describe areas of high-risk in New Jersey and guide public health efforts in Kentucky.[10,11]

The objective of this study is to use GIS methodology to determine which areas in Charleston County, South Carolina, are considered high-risk for lead poisoning based on the age of housing. In addition, we wish to assess the utility of GIS in developing a targeted lead-screening program.

METHODS

Construction of the database

Childhood lead-screening data for the Charleston County Lead Poisoning Prevention Program were maintained in the Systematic Tracking of Elevated Lead Levels and Remediations (STELLAR) software.[12] The STELLAR data are maintained in several relational files: (*a*) a child file containing child demographic information; (*b*) an address file containing addresses that can be linked back to a child; and (*c*) the lab file, containing all lead laboratory test results. One child could have multiple tests, and similarly one child could have several home addresses. The Lead Program provided data for all children screened from 1991 through August 1998. Names were not included so that an individual child could not be identified. We examined data for all children screened from 1991 through August 1998 (excluding children's names to preserve confidentiality). Addresses in the STELLAR records were geocoded (assigned latitude and longitude coordinates) using Matchmaker/2000 address matching software.[13]

The Charleston County Tax Assessor's Office provided the following data on residential housing: (1) built before 1950; (2) built from 1950 through 1977; and (3) any properties missing year built data. Properties built before 1950 were checked against the 1950–1951 Charleston City Directory, and properties built from 1950 through 1977 were checked against the 1978 Charleston City directory to verify that the address existed at that time. All non-geocodable addresses (Post Office Box, Rural Delivery) were deleted. Next, the data were entered into SAS software[14] and duplicate addresses (such as from duplexes, apartment complexes, and so forth) were deleted. The data were then geocoded. The tax assessor files were merged with the STELLAR records. All data cleaning, merging, and analysis were done using SAS.

Visualization of the Data

All data were entered into Maptitude 4.2 Geographic Information System.[15] Lead poisoning cases (blood lead levels ≥10 µg/dL) and all lead screens were created as separate map layers. Quality assurance checks verified that for every "case" the same location had a "screen." Tax assessor data (pre-1950 and 1950–1977 housing) were also created as separate map layers. These map layers were incorporated into a map containing the following geographic census layers for Charleston County: census places (cities and towns), census tracts, block groups, and streets. To maintain consistency with recent CDC recommendations, the housing categories were pre-1950, 1950–1977, and post-1977.[6]

Data Analysis

We calculated prevalence ratios of positive cases among children who were screened for lead poisoning. Relative risks with 95% confidence intervals were determined comparing prevalence in 1950 housing and 1950–1977 housing to that of post-1977 housing. Within the 1950–1977 housing age category, we also calculated the risk at smaller intervals (1950–1955, 1956–1960, and so on) to determine whether older houses within the 1950–1977 category posed a different risk than a newer one. We also compared data among ZIP Codes.

The Institutional Review Board at the Medical University of South Carolina approved this project.

RESULTS

From tax assessor data, 13,003 addresses were identified as pre-1950. Of these, 321 were deleted as unusable because they represented a Post Office (P.O.) Box or Rural Delivery. Of 12,682 of the remaining properties, 12,341 were geocoded (assigned a latitude and longitude), identifying 97.3% of houses. Once duplicate addresses were removed (duplexes, apartments, and so forth) using SAS software, there were 10,812 unduplicated pre-1950 addresses. In the 1950–1977 tax assessor dataset, 40,285 were identified, 822 were deleted as P.O. Boxes or Rural Delivery, and 38,081 (96.5%) of the properties were geocoded. Once duplicate addresses were deleted, we identified 37,144 houses built from 1950 through 1977.

In the STELLAR file, 600 P.O. Boxes and Rural Districts were deleted from the 16,040 addresses. Of the remaining 15,440 addresses, 14,957 were geocoded (96.9%). After merging the lab and child files with the address file, we had 34,792 geocoded STELLAR records representing the location of all Charleston County children tested with a blood lead level. The larger number of STELLAR records compared to the number of addresses is partly a result of numerous siblings or cousins sharing the same home, but mostly represents multiple follow-up lead tests for those children with elevated blood lead levels (EBLLs). After removal of duplicate tests, we determined that 1,710 children lived in pre-1950 housing, 3,715 lived in housing built from 1950 through 1977, and the remaining 9,847 children lived in post-1977 housing.

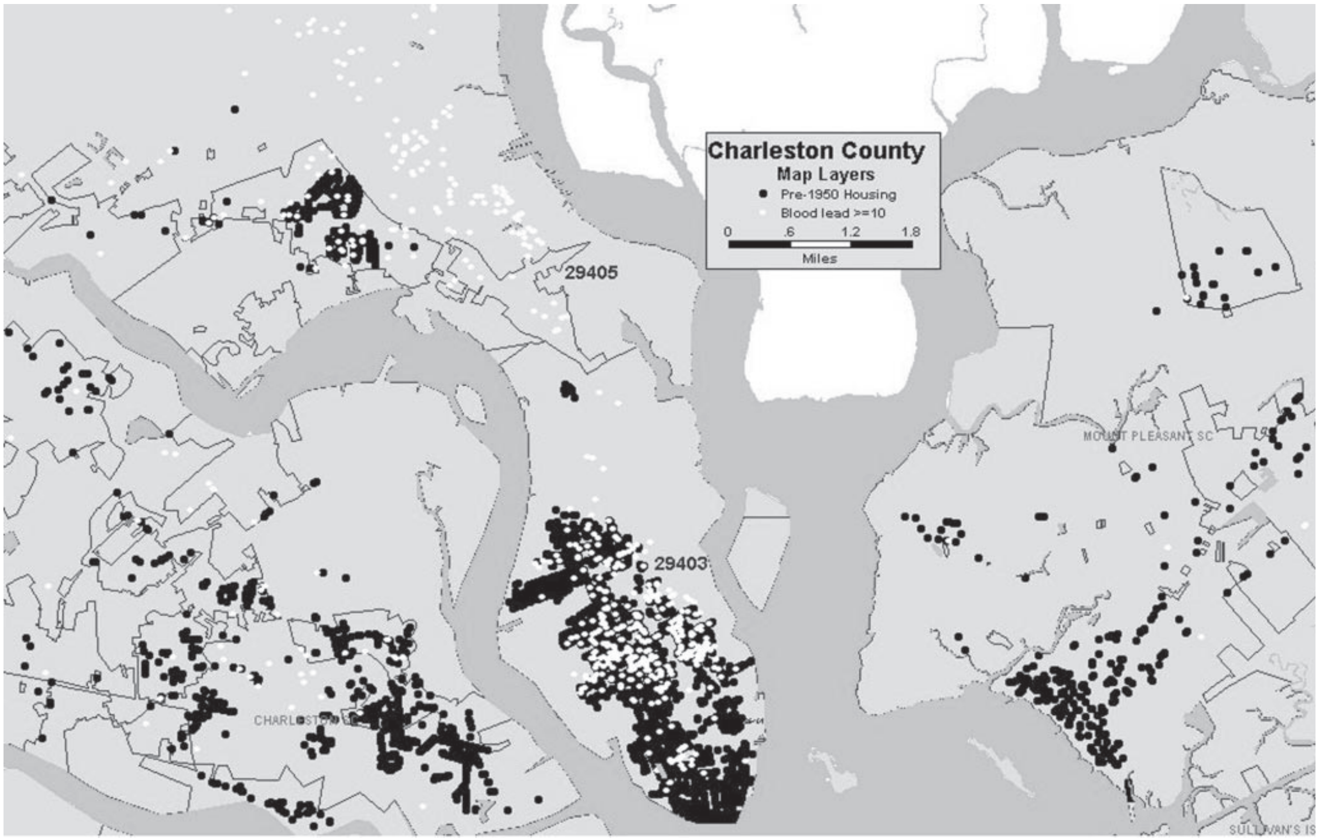
Figures 1 and 2 show Charleston County and an enlargement of the lower end of the peninsula of the City of Charleston.[15] Each map displays the locations of all houses built before 1950 and the location of all children with blood lead levels of ≥10 µg/dL. The lower end of the peninsula of Charleston is where almost all early settlement occurred and is where a substantial number of lead poisoned children are located. The map demonstrates that most of the cases are located in pre-1950 houses. In several areas of Charleston County, there are areas with a high concentration of pre-1950 housing, but little screening activity.

The number of cases found and their association with age of housing is presented in Table 1. One third of the lead poisoned children lived in pre-1950 housing; 17% lived in homes built from 1950 through 1977; and 49.5% lived in homes built after 1977. However, there were more than five times the number of children screened who live in post-1977 housing compared to children living in pre-1950 housing. Children living in pre-1950 housing were four times more likely to be lead poisoned than children living in housing built after 1950. There was no statistically significant difference in risk for lead poisoning among children living in housing built from 1950 through 1977 compared to housing built after 1977. The 1950–1977 housing category was divided equally into four subcategories to determine whether houses, such as those built in the early 1950s or 1960s, may pose some risk; however, no risks were found.

Table 2 presents data for screening activity, the number of cases, and the percentage of cases per children screened, as stratified by ZIP Codes. The last column of the table represents the percentage of cases in that ZIP Code associated with residence in pre-1950 housing. The largest number of cases (578) were located in ZIP Code 29403 (Figure 2). More than half of the children in this ZIP Code with EBLLs live in pre-1950 housing. Of those children not residing in a pre-1950 house, all are in immediate proximity to pre-1950 housing. Despite relatively limited screening activity in the 29401 ZIP Code, an area with very expensive but well maintained homes, almost 16% of the children screened were positive.

Figure 1. Map of Charleston County

All houses built before 1950 are shown in black. The white dots represent all locations of lead poisoning cases.



In contrast, the next largest number of cases (225) were located in the 29405 ZIP Code, but only 15 (6.7%) of these children resided in a pre-1950 house (Table 2). This region can be seen in Figure 3. Pre-1950 housing is much more limited in this area, with approximately 1,005 pre-1950 houses in this ZIP Code; yet the percentage of lead poisoned children in pre-1950 housing was nearly identical to that of the whole region, regardless of age of housing. Of the 225 cases in this ZIP Code, 171 (76 %) are found in post-1977 housing, suggesting an additional exposure apart from housing may exist. Little screening activity was noted in some pre-1950 neighborhoods for many other ZIP Codes in Charleston.

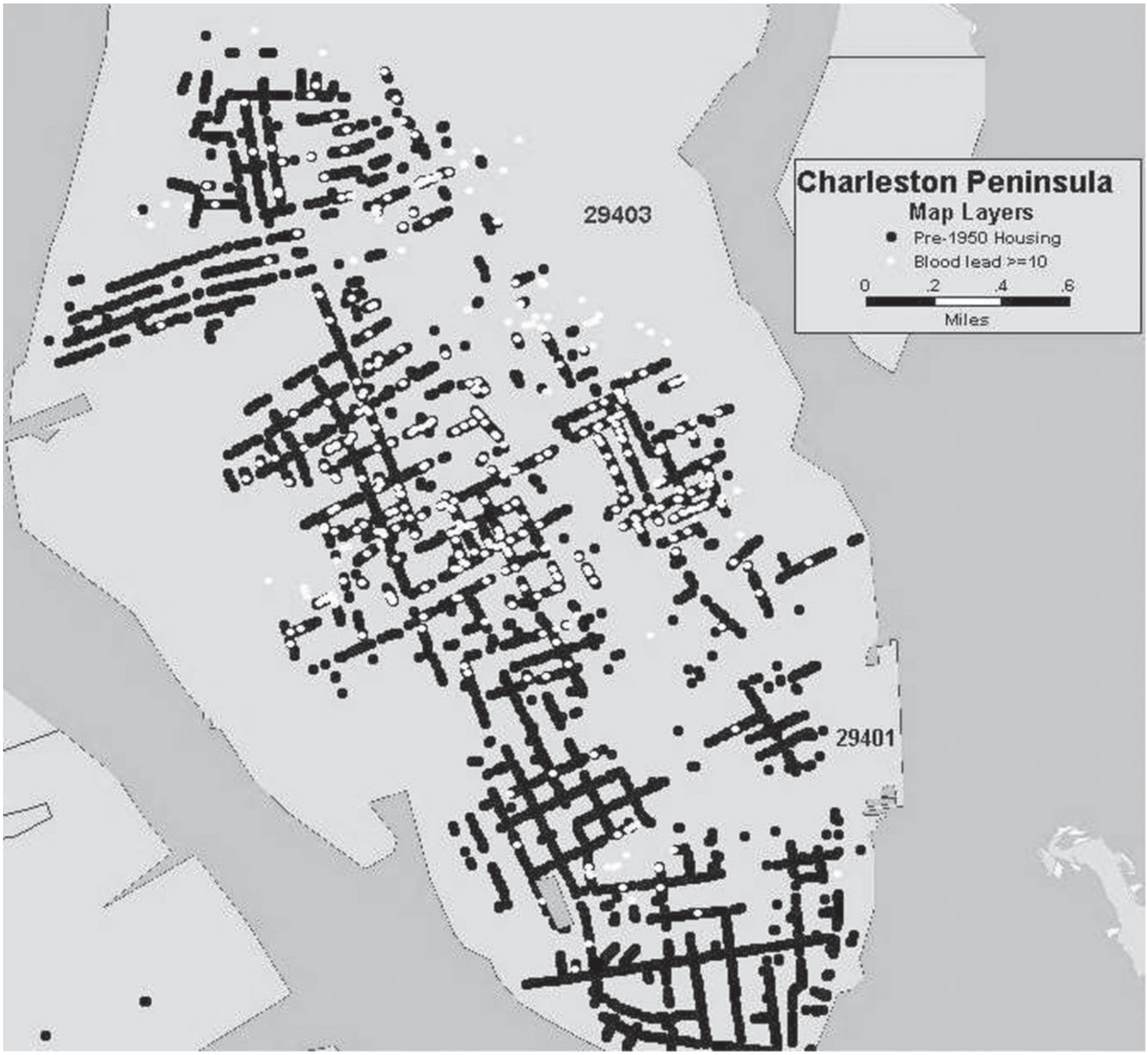
DISCUSSION

Our study supports the finding that housing is a known risk factor for lead poisoning by providing geographic evidence supporting pre-1950 housing as a primary risk factor. In our population, the children who lived in pre-1950 homes had a relative risk of 3.9 for acquiring lead poisoning. We did not find a higher risk for lead poisoning among children living in 1950–1977 housing, neither as a category, nor in five-year increments after 1950. This may be due to the fact that prior to 1950, the concentration of lead in paint was considerably higher, than from 1950 through 1977. During this period, before lead-based paint was banned for indoor and residential use, there was a voluntary reduction by the paint industry in the concentration of lead used in paint.[16]

Our study also provides evidence that GIS is useful to determine where flaws in the housing risk assessment model lie. Had housing age been the only risk factor with which to target lead screening, a large number of cases would have been missed in the North Charleston area. GIS allows additional risks to be iden-

Figure 2. Closeup view of the tip of the peninsula in Charleston, which is the site of the original Settlement

Most cases are associated with residence in pre-1950 housing.



tified and factored into a targeted screening plan. The cluster of cases that were found in post-1978 housing in North Charleston is one example. Another study has documented outdoor environmental soil contamination using GIS techniques, due to automobile exhaust.[17] Further investigation into this cluster is in progress and will be the subject of a future article.

Two other important findings are worth special mention. Several areas in which there were large numbers of pre-1950 housing were noted to have an absence of screening. Without GIS, one would easily overlook these potential target areas where screening should occur. Also, a significant number of cases were noted in children living in newer housing, but in a geographic region surrounded by a high concentration of pre-1950 housing. If screening for these chil-

Table 1. Percentage of cases per children screened from 1991 through 1998 in Charleston County

Age of house	*Children Screened*	*Cases*	*Cases/Screened*	*All Cases*	*Relative Risk*[a]	*95% Confidence Interval*
Pre-1950	1,710	349	20.4%	33.4%	3.9	3.4, 4.4
1950–1956	906	49	5.4%	4.7%	1.0	0.8, 1.4
1957–1963	881	37	4.2%	3.5%	0.8	0.6, 1.1
1964–1970	1,020	41	4.0%	3.9%	0.8	0.6, 1.1
1971–1977	908	51	5.6%	4.9%	1.1	0.8, 1.4
Post-1977	9,847	517	5.3%	49.5%	1.0	REF
Total	15,272	1,044				

[a]RR in relation to Post-1977 housing

REF = referant

Table 2. Risk of lead poisoning by neighborhood and ZIP Code

	ALL HOUSING			*PRE-1950 HOUSING*			
ZIP Code	*Screened*	*Cases*	*Cases/Screened*	*Screened*	*Cases*	*Cases/Screened*	*Cases in ZIP Code due to pre-1950 housing*
29401	274	43	15.7%	78	8	10.3%	18.6%
29403	2,733	578	21.2%	1,186	319	26.9%	55.2%
29405	3,259	225	6.9%	248	15	6.0%	6.7%
29406	1,978	37	1.8%	0	0		
29407	1,466	54	3.7%	49	1	2.0%	1.9%
29412	852	20	2.3%	48	1	2.1%	5.0%
29418	1,243	22	1.8%	6	3	50.0%	13.6%
29455	546	15	2.8%	5	0	0%	0%
29464/66[a]	719	11	1.6%	49	1	2.0%	9.1%
All others[b]	2,165	39	1.8%	39	1	2.6%	2.6%

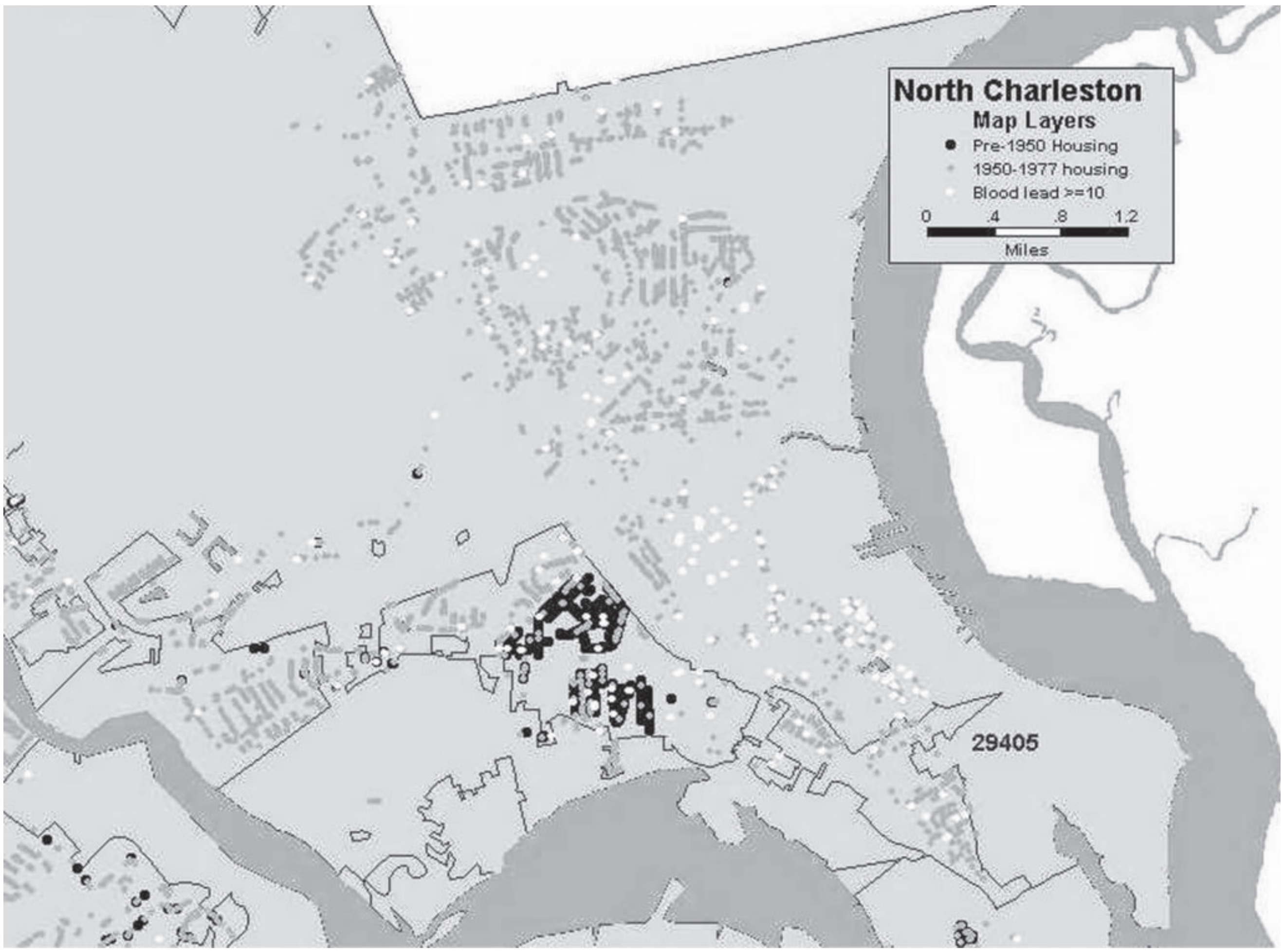
NOTE: In 29406, 29407, 29412, 29418, 29455, and 29464/66, very little screening of children living in pre-1950 housing occurs. Past screening in a lot of these areas has been focused on testing the pre-K and kindergarten children through schools.

[a]Represents town of Mount Pleasant—ZIP Codes combined due to small numbers of screens

[b]Represents ZIP Codes in which 10 or fewer lead poisoning cases were found

Figure 3. Segment of the city of North Charleston, which can be found on the County map as the northern-most part of the peninsula

A small number of homes (shown in black) were built before 1950. A much larger proportion of the homes were built after 1950. (1950–1977 housing are shown in gray; houses built after 1978 houses are not shown due to the overwhelming number of houses in the area of question). A large number of cases (shown in white) were found in children who lived in housing built after 1950.



dren relied solely on parental report of the age of their residence, it is likely that few of these would have been screened. GIS should be a focal point for determining risk for any public health lead-screening plan.

In communities, such as rural areas with limited resources to complete a study with GIS, our results could be used to modify or develop a concentrated approach to lead screening. First, there should be an attempt to identify at the local level the neighborhoods that fit the profile for risk, including poverty, race/ethnicity, and old housing. Next, there should be local knowledge of any potential point sources in the community, and these should be considered in any model. Finally, rather than using a questionnaire to determine which children should be screened, one should do mass screening of those neighborhoods or even roads or houses to establish the prevalence. Arguably, it is the rural areas that may be at greater risk, where, unlike most urban areas, there is no concentrated screening program.

Methods used in the geocoding process for the construction of this database yielded a successful geocoding ratio of 97% or better. This is due in large part to careful use of resources to insure accuracy of street names, and thorough verification of addresses using the city directory. This accuracy is at least as efficient as or better than most commercial geocoding firms and the U.S. Bureau of the Census.[18]

This study has several limitations. Due to the retrospective nature of the data, we are unable to differentiate individual risk patterns per case. These include additional soil contamination, pica, the presence of lead-contaminated mini-blinds, and whether the child spent a significant amount of time in a home of a relative or babysitter that may have been built before 1950. The soil contamination often occurs from old deteriorated housing, though contamination from point sources or automobile exhaust are additional considerations. The latter issue would actually misclassify a child with a post-1977 address as low risk. These data are predominantly of South Carolina Medicaid recipients. Although these data arguably represent the children at highest risk, there is a possible underreporting of the risk in some areas of Charleston. Most notably, the ZIP Code of 29401 consists of a high percentage of old but often well maintained and high-priced homes. Though a small number of children have been screened in this area, a significant number of cases have been found there. Our data possibly represent an underestimation of the actual risk for this group of children.

By creating a map of all the data, GIS allows one to visualize the population at once. This allows quick assessment of case location, resources spent on lead screening, and potential risk factors. Once this information is seen graphically, public health officials or practitioners have a greater understanding on how to assess past performance of a lead screening program, evaluate the risks, and develop a methodical and practical approach to screening.

The clustering of lead poisoning cases makes GIS an ideal mechanism for identifying new cases based on geographic risk. One can quickly determine from GIS where old houses are located and predict where lead poisoned children would most likely be found. This information can be combined with census data to take into account socioeconomic factors, allowing targeted lead screening efforts and/or primary prevention interventions in neighborhoods with the highest concentration of pre-1950 housing and children living in poverty.[6] GIS may be useful for state or local public health officials as they develop a targeted lead-screening program as outlined by the CDC. It also clearly and simply articulates risk to the public, and therefore may be useful as an outreach tool for public health programs as they develop outreach interventions.

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