# Environmental injustice, public health and solid waste facilities in North Carolina


by
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**ABSTRACT**

JENNIFER M. NORTON: Environmental injustice, public health and solid waste facilities in North Carolina

(Under the direction of Steve Wing)

Community groups in North Carolina are concerned that solid waste facilities may be disproportionately located in non-white and low-wealth communities, that this represents an environmental injustice, and that solid waste facilities negatively impact the health of host communities. However, the relationship between environmental injustice and health has not been fully evaluated. A conceptual model was developed as a basis for exploring the relationships between environmental injustice, solid waste, and health. While this model includes health impacts associated with direct exposures to toxicants, the emphasis is on the indirect effects of solid waste facilities on health through their impacts on the built environment. This model was used to inform analyses that evaluated the prevalence and occurrence of solid waste facilities in non-white communities compared to white communities and low-wealth communities compared to high-wealth communities in North Carolina. Communities were defined as census block groups in order to obtain information on racial and economic characteristics. Information on solid waste facilities was obtained through a review of solid waste facility records maintained by the North Carolina Division of Waste Management. The results of these analyses suggest that on average in North Carolina, the prevalence of solid waste facilities in 2003 was greater in non-white communities (50 to 100% non-white) compared to white communities (<10% non-white) (adjusted prevalence odds ratio [adjPOR]: 2.8; 95% confidence interval [CI]: 1.9, 4.1); and low-wealth communities (median house values <$60,000) compared to high-wealth communities (median house values ≥$100,000) (adjPOR: 1.5; 95% CI: 0.9, 2.5). Among block groups that did not contain a previously permitted solid waste facility, the occurrence of solid waste facilities permitted between 1990-2003 was greater in non-white communities compared to white communities (adjusted hazard ratio: 2.7; 95% CI: 1.3, 5.7). Solid waste facilities present numerous public health concerns including potential for water contamination, traffic safety, malodors, and impacts on health promoting resources. As proposals to site additional solid waste facilities in North Carolina are discussed, these results should be considered to minimize the disproportionate impacts on non-white and low-wealth communities.

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| | |
|---|---|
| CDLF | Construction and demolition debris landfill |
| CDP | Census designated place |
| CI | Confidence interval |
| COMPOST | Compost / yard waste landfill facility |
| GEE | Generalized estimating equations |
| GIS | Geographic Information System |
| HHW | Household hazardous waste facility |
| HR | Hazard ratio |
| INCIN | Incinerator |
| INDUS | Industrial solid waste landfill |
| LCID | Land clearing and inert debris landfill |
| MSWLF | Municipal solid waste landfill |
| MWP | Mixed waste processing facility |
| NGS | National Geodetic Survey |
| NOAA | National Oceanic and Atmospheric Administration |
| NC | North Carolina |
| NCCGIA | North Carolina Center for Geographic Information Analysis |
| NCDWM | North Carolina Division of Waste Management |
| POR | Prevalence odds ratio |
| PTC | Permit to construct |
| PTO | Permit to operate |
| SES | Socioeconomic status |
| SWF | Solid waste facility |
| TIRELF | Tire landfill |

| | |
|---|---|
| TP | Treatment & processing facility |
| TRANSFER | Waste transfer station |
| UAUC | Urbanized area / urban cluster |
| US | United States |
| USEPA | United States Environmental Protection Agency |
| USGS | United States Geological Survey |

# CHAPTER 1

# INTRODUCTION

## A. Background and significance

Community groups in North Carolina have expressed concern that solid waste facilities may be disproportionately located in non-white and low-wealth communities. These concerns include a number of public health issues. For example, solid waste landfills are a source of potential exposures to groundwater contaminants (17) and to odorous and non-odorous gases (3). Trucks that transport waste to and from solid waste facilities are a source of potential exposures to vehicle emissions (31) and could pose injury risk to pedestrians, cyclists, and occupants of other motor vehicles. Furthermore, solid waste facilities may impact community resources, which can affect community and individual health.

The concern that non-white and low-wealth communities may host a disproportionate burden of solid waste facilities is an environmental injustice issue. Reviews of the environmental injustice literature are available elsewhere (10, 11, 22, 27). Two examples of environmental injustice concerns related to proposed municipal solid waste landfills in North Carolina are discussed. These local cases highlight some of the broader conceptual and methodological issues that are debated in the literature. These issues include geographic scale, temporality, and the connection between environmental injustice and health (5, 8, 12, 13, 24).

### *1. Case example 1: Greene County*

Greene County is a rural county in eastern North Carolina. The Greene County Board of Commissioners entered into an agreement with a private waste management company to construct a municipal solid waste landfill that could accept waste from the entire state of North Carolina. Citizens of Greene County took legal action against the Board and waste company on the basis that the county failed to meet the requirements of North Carolina General Statute [NCGS]153A-136c. This statute requires the county to conduct a socio-economic assessment and consider alternate sites when a landfill is proposed within one mile of an existing landfill. The North Carolina Court of Appeals ruled in favor of the citizen group (2).

Two reports were prepared on behalf of the owners of the proposed landfill (6, 32). These reports were presented to the Greene County Board of Commissioners and were included as part of the landfill permit application submitted to the North Carolina Division of Waste Management. The authors of these reports concluded that no environmental injustice concerns were present at the proposed site. The citizen group requested the assistance of academic researchers to review the methodology used in the reports. A critical review of these reports revealed numerous technical inaccuracies, including discussion of results that misrepresented census geographic units used in the analyses (33, 34).

Based on the year 2000 Census, 42% of the 18,974 residents of Greene County were African-American (30). The census block group that would host the proposed municipal solid waste landfill was 24% African-American [286 /1,214]. Census block groups are the smallest geographic unit for which socio-economic data, such as income and education, are released. However, basic demographic data, such as race and age are released at the census block level. The census block more closely reflects the immediate neighbors of the proposed landfill who may be more directly impacted by the potential environmental pollutants associated with landfills. The census block that would host the proposed landfill was 62% African-American [77/124]. Figure 1.1 illustrates the location of the proposed landfill in relation to the block and block group African-American population.

In 2001, the North Carolina Division of Waste Management issued a permit to construct to the owners of this municipal solid waste landfill. However, the owners relinquished this permit before the landfill was constructed (1).

The Greene County example highlights the issue of geographic scale, including the scope and unit of analysis. From a methodological standpoint, the unit of analysis is important due to the modifiable areal unit problem (19). The unit of analysis is related to the scope of the analysis. In the Greene County example, multiple scales could be considered. The landfill that was proposed for Greene County would have accepted municipal solid waste from the entire state of North Carolina. Greene County has the third lowest per capita waste disposal rate of all 100 counties in the state (16). The relationship between solid waste and scale is further explored in the next chapter.

### *2. Case example 2: Holly Springs*

In 1990 Holly Springs was a small, predominately African-American community located in southwest Wake County. According to 1990 Census data, approximately 78% of the 908 residents in Holly Springs were African-American. In 1992, prior to the enactment of the NCGS 153A-136c legislation, Wake County Commissioners selected Holly Springs to host a new lined municipal solid waste landfill for the disposal of waste produced in Wake County (28). The new landfill was proposed to be located on land adjacent to the existing Feltonsville landfill. The Feltonsville landfill began operation in 1974 and continued to accept municipal solid waste through 1997. Like many other unlined municipal solid waste landfills across the state, the Feltonsville landfill did not meet the federal and state requirements to continue accepting municipal solid waste for disposal after January 1, 1998. However, since the landfill had remaining capacity for waste disposal, Wake County applied for a permit to operate a construction and demolition debris landfill on top of the capped municipal solid waste landfill. This permit was issued by the North Carolina Division of Waste Management. A waste transfer station was also permitted at this site to consolidate waste for transfer to the North Wake landfill for disposal. In addition to these three solid waste facilities, the Holly Springs area has at least two known pre-regulatory dump sites, three permitted construction and demolition debris landfills, one land clearing and inert debris landfill, one compost facility, and one unlined municipal solid waste landfill (1, 28).

During the 1990's, the Town of Holly Springs experienced tremendous growth, partly due to its proximity to the Research Triangle Park. According to the 2000 Census, the population of Holly Springs had grown to 9,192 residents, of which 76% were White. In addition to this population growth, the town boundary of Holly Springs increased over this time period. This was due to the annexing of certain new housing developments built to accommodate and attract population to the area. Figure 1.2 illustrates the location of permitted solid waste facilities near Holly Springs, the percent African-American population in year 2000 census blocks, and housing developments as indicated by the Wake County tax parcel property boundaries. Although the population growth in Holly Springs resulted in a demographic shift from a small predominately African-American community to a medium size predominately white suburban community, it should be noted that many long-term African-American community members still reside in Holly Springs.

Although the local government decision to site the landfill in Holly Springs was made in 1992, the first permit to construct was issued by the North Carolina Division of

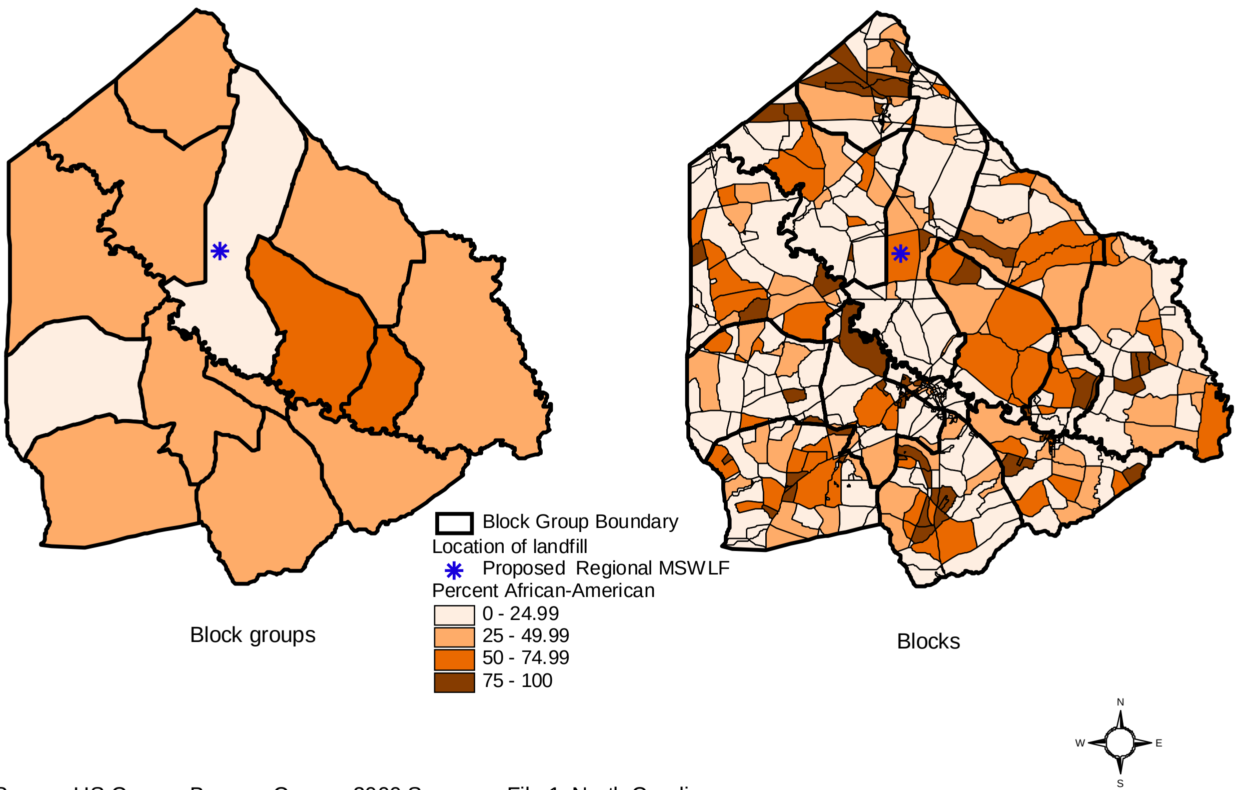
Waste Management in 1999. This original permit was nullified by an Order of the Wake County Superior Court in 2000. In 2001, a permit to construct was re-issued for this facility (1). Despite the permit issuance, as of spring 2006, the facility has not yet been built due to debates and legal battles. However, Wake County Commissioners voted in June 2006 to proceed with construction to operate the landfill in Holly Springs within two years (7).

The Holly Springs example highlights the temporal relationship between community demographics and facility siting. In the environmental justice literature this has been referred to as the chicken-or-egg debate (22) and the which-came- first question (20). As this example shows, at the time the local government decision was made to build the landfill in Holly Springs, the town was predominately African-American. At the time the permit to construct was issued by the state, nearly 9 years later, the town was predominately white.

**B. Research goals**

The experiences of the Greene County and Holly Springs communities provide two examples of environmental injustice and solid waste in North Carolina. Although these examples provided valuable information, the extent to which these experiences were unique or represented a small part of a larger picture were unknown. The overall goal of this dissertation research is to address the environmental injustice concern that solid waste facilities may be disproportionately located in non-white and low-wealth communities in North Carolina. This research goal is salient in light of current proposals to build municipal solid waste landfills in the state of North Carolina which, if approved, could make the state the fourth largest importer of municipal solid waste in the country (23). Furthermore, with the focus on solid waste facilities this study will add to the literature on environmental injustice, which has focused on hazardous waste facilities (4, 9, 14, 15, 18, 20, 21, 25, 29).

Although some researchers have called for a more explicit connection between environmental injustice and health (12, 24, 26), this relationship has not been fully explored. To address this gap, a conceptual model was developed that can be used to describe and more fully explore possible relationships between environmental injustice, solid waste, and health.




Source: US Census Bureau, Census 2000 Summary File 1, North Carolina
Note: African-American population reflects all responses of African-American race

**Figure 1.1: Location of proposed regional municipal solid waste landfill [MSWLF] and percent African-American population: Census block groups and blocks, Greene County, NC**

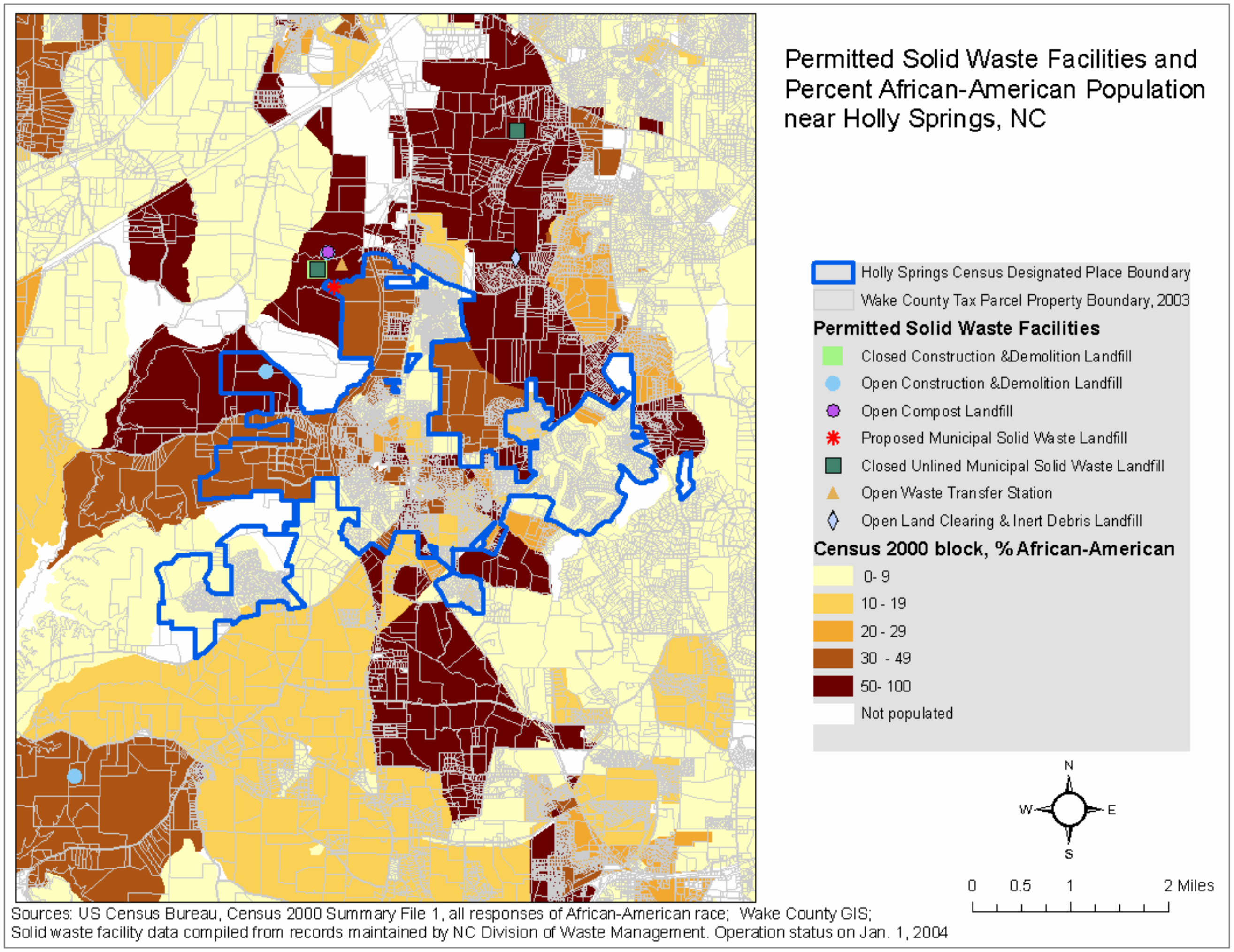



**Figure 1.2: Permitted solid waste facilities, property boundaries, and percent African-American population in Census blocks near Holly Springs, NC: 2000**

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# CHAPTER 2

# BALANCING THE SCALES:

# A CONCEPTUAL MODEL FOR ENVIRONMENTAL INJUSTICE, SOLID WASTE, AND HEALTH

## A. Introduction

Materials that are produced and consumed in the United States create harmful by-products that are disproportionately borne by low-wealth and non-white communities (31). Examples of this environmental injustice are evident from the toxic air emissions (50, 51) and hazardous wastes (62) created through manufacturing processes, to the volume of animal wastes created through industrialized mass food production (74, 77). These environmental hazards pose potential risk to public health and the environment, but one criticism of the environmental injustice literature is that health impacts of these hazards are not evaluated (7, 52).

The purpose of this paper is to introduce a conceptual model that can be used to describe and more fully explore possible relationships between environmental injustice, solid waste, and health. This conceptual model was developed to inform empirical research conducted in North Carolina. Although solid waste management and environmental justice concerns are of global importance, this paper focuses on the United States.

There are several key themes in the proposed conceptual model: health, built environment, environmental injustice and scale. The World Health Organization (1) defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." This broad definition of health allows the realm of epidemiological inquiry to be expanded from a focus on disease outcomes. For example, the ability to enjoy spending time outdoors without the intrusion of environmental malodors may contribute to mental and physical well-being. Factors that contribute to well-being should be considered important aspects of research interest, and not merely ancillary nuisance factors. A further expansion is made through the acknowledgment of community health in promoting and maintaining individual health.

There is renewed interest in the relationships between the built environment and health (47, 58). The built environment can be defined as the buildings, open areas, and infrastructure created and maintained by human action. Recent research has examined how the built environment affects human health through the opportunities for physical activity (27) and the food available at the local grocery store (44). Differential access to these necessities and differential quality when accessed, based on race and class have also been examined (26, 45). The health impacts of the built environment are often conceptualized as indirect effects, meaning that these conditions interact to produce, maintain, and facilitate direct exposure to health promoting and health limiting factors.

Some built environments include unwanted land uses (8). Factors such as the principles of agglomeration (13) and zoning laws (38) serve to concentrate these environmental hazards in certain areas, to the potential detriment of health promoting resources such as schools, health clinics, and food stores. The relationship between the location of environmental hazards and race and class of communities has been evaluated in numerous empirical studies of environmental injustice.

That environmental injustice operates at multiple scales (30, 33, 61, 73) is crucial not only from a public health viewpoint, but also from a public policy viewpoint. It is important to recognize that scale is not fixed, but rather is socially and politically constructed (39, 54, 56). The scale at which the problem is produced, the scale at which the problem is experienced, and the scale at which the problem can be resolved must all be considered when evaluating environmental injustice.

## B. Conceptual model: Solid waste, environmental injustice and health

Solid waste management has long been a public health concern and waste management practices have presented environmental injustice concerns (8). However, the connections between solid waste, environmental injustice and health have not been fully explored. This model offers one way to conceptualize and investigate these relationships.

### *1. Solid waste*

First, it is important to clarify the definition of solid waste as used in this model. The most general definition of waste is something that is no longer wanted or needed. This definition implies a subjective individual interpretation [*e.g.,* "one person's trash is another person's treasure"], but it is important to note that the definition of waste is culturally and temporally based (59). In general, solid waste refers to solid or liquid materials that are discarded through a wide range of activities related to mining, agriculture, construction, demolition, and land-clearing processes in addition to the more common notion of garbage or municipal solid waste. For the purpose of this model, the term solid waste is used to refer to garbage and construction waste generated by residents and businesses (69).

Figure 2.1 outlines the conceptual model used to describe the relationships between solid waste, environmental injustice, and health. The complex ideas and notations are simplified for presentation purposes. A key element of this model is the inclusion of feedback loops, represented by double headed arrows.

Solid waste landfills provide a useful starting point for discussion. As depicted in Figure 2.1, solid waste landfills are connected to political-economic and social relations at various geographic scales that influence solid waste production and solid waste management decisions. The discussion below highlights some aspects of this connection.

Waste has always been produced, however, the amount and types of waste produced are embedded in a socio-historical context (41). The contemporary American political-economic system creates, maintains and reinforces the production of waste through the consumption of new consumer products (11). In the last forty years, there has been tremendous growth in the amount of municipal solid waste produced in the United States, from 88 million tons in 1960 to 236 million tons in 2003 (66). While population growth accounts for some of this increase, the per-capita national disposal rate has increased from 2.7 pounds per person per day in 1960 to 4.5 pounds per person per day in 2003 (66).

Urbanization necessitated organized solid waste management practices and such practices have been in existence since ancient civilization (36). Waste disposal methods have changed over time due to changes in societal organization, politics, economics, culture, and public health practices (36, 68). Contemporary waste management strategies incorporate an integrated waste management hierarchy (67). The most preferred method of waste management is source reduction [including reuse of products], followed by recycling, and combustion/landfilling of the remaining waste.

Although it is the least preferred waste management strategy, the majority of waste produced in the United States is disposed in landfills (67). One suggested reason for this is the low cost of landfills relative to other waste management options (41). The lack of federal policies to promote alternative options may also contribute to this trend, as the following example illustrates.

In theory, the idea of source reduction is most similar to the public health goal of primary prevention. In practice, it is recycling that shares similarities with many public health interventions, with the emphasis on individual behavior change to increase recycling of materials. Responsibility for recycling falls under local government jurisdiction to provide necessary infrastructure and individual initiative, rather than corporations who produce and profit from the product (53).

One ramification of this current structure was exemplified when New York City [NYC], the most populated city in the United States, announced that it would limit its recycling program because it was not economically feasible to continue collecting plastics and glass in a time of financial crisis for the city (19). This announcement came at a time when NYC had no active waste disposal facility within city limits. Although NYC re-implemented its plastics and glass recycling (60), similar decisions to reduce recycling efforts in the future could have direct consequences for other states. Discussions are in process to transport NYC trash to ports in Virginia where it will be re-transferred by truck to North Carolina for final disposal (4). The relationship between scales is also exemplified in this case: the decision to end or limit recycling programs in one municipality has impacts for other areas that accept that waste for final disposal.

Many factors at the federal, state and local level have contributed to current waste management practices. As the example above highlights, waste collected locally is not always disposed locally. One reason is that the United States Supreme Court has ruled that waste is a commodity, and as such is protected by interstate commerce laws (75). The free trade of waste across state borders is affected by individual state policy. For example, the state of North Carolina does not charge a disposal fee for out of state waste. This fact combined with the state’s central location along the eastern US coast, may be contributing to recent proposals to build large landfills in North Carolina to handle wastes produced in other states (28).

Federal regulatory changes implemented in October 1993 have also affected waste management practices (65). These regulations were passed in part due to health and environmental concerns (65). In order to reduce the opportunity for pollution from municipal solid waste landfills [MSWLF], changes in engineering designs to incorporate liners and leachate collection systems were required (65). To reach an economy of scale given the additional construction costs associated with this regulation, the size of MSWLFs increased and the number of active MSWLFs declined from 7,924 in 1988 to 1,967 in 2000 (67). Since there were fewer active MSWLFs, the average distance between the point of waste generation and waste disposal increased and resulted in the construction of additional waste transfer stations, facilities which consolidate waste to be transferred for final disposal.

Another consequence of the regulations has been a more refined classification of waste types. For example, construction and demolition waste, yard waste, and other land clearing waste that once were disposed in MSWLFs are separated and disposed of in facilities solely for those wastes. Although these individual landfill facilities may now differ in terms of the types of solid waste they receive, these facilities are often located at the same solid waste complex. The agglomeration of different types of waste facilities in one location is expected since the land may already be zoned for that use and infrastructure may be in place [*e.g.*, weigh scales, roads, heavy equipment]. The agglomeration of waste disposal sites is therefore rationalized as being economically sound.

An environmental justice perspective leads to the question, which communities produce the waste and which communities live with the consequences of its disposal? These questions are often addressed at the local level and are predicated on the existence of communities that differ by race and class. Racial and class segregation has historical roots in federal and state policy. For example, federal housing and transportation polices resulted in the destruction of existing African-American communities whose residents were up-rooted to areas of concentrated poverty (20, 40).

In Figure 2.1, all of these factors described above contribute to the feedback loop between solid waste landfills and solid waste production. To simplify the point, the majority of wastes produced are disposed in landfills, which are increasingly sited farther away from the point of waste production. This may reduce incentives for decreased waste production since the consequences of waste disposal are experienced elsewhere. The next section explores the possible connections between solid waste landfills and health.

### *2. Solid waste and health*

Improvements in organized solid waste collection and disposal are among the factors that contributed to the control of infectious diseases, which is considered one of ten major achievements in US public health in the $20^{th}$ century, according to the US Centers for Disease Control and Prevention [CDC] (10). Yet, waste management practices continue to present health and environmental concerns. One of the reasons for stricter regulation of MSWLFs was to help safeguard the environment and public health (65). Across the country, older unlined landfills were found to be contaminating groundwater (65) and uncontrolled methane gas emissions were contaminating air and posed risk for explosions (64). The new regulations were aimed at limiting the pollution potential, however, pollution from these sources cannot be totally eliminated.

As illustrated in Figure 2.1, landfills can directly affect health of exposed populations not just through contamination of water and air, but also by factors such as noise pollution and traffic.

Trucks transporting waste to landfills and transfer stations present traffic safety concerns to motorists, bicyclists, and pedestrians along transportation routes (15, 71). Residents living along the transportation routes may also be impacted by traffic noise and residents living in close proximity to active landfills and transfer stations may be impacted by noise exposures from daily activities at the facility. Noise exposures can affect well-being and induce stress (49).

When water comes in contact with waste disposed in landfills, leachate is formed. If a landfill is unlined, leachate can more readily enter groundwater or surface water. Lined landfills are designed to minimize the potential for leachate to enter the water system, but design malfunctions are not eliminated. Once in the water system, leachate can contaminate the aquifers that are used or might be used in the future as a water supply. Human exposure can occur through drinking the water, bathing, or consuming fish caught from the contaminated water bodies (32). Low-wealth populations who rely on fishing from local waterways to supplement their nutritional intake may be disproportionately exposed to this contamination (9).

Landfill activities present multiple sources of air emissions. Solid waste is transported to landfills via diesel fueled trucks. Earth moving machinery used in daily landfill activities also emit diesel exhaust. Diesel exhaust is a likely human carcinogen (70). Furthermore, diesel exhaust contains fine particulate matter that can cause and exacerbate respiratory conditions and contribute to premature death (70). However, exposures to diesel exhaust occur over short distances.

Landfill gases are produced through bacterial decomposition, volatilization, and chemical reactions (2). Gases are produced in landfills long after active waste disposal stops. A variety of factors influence the composition of landfill gases, including the type of waste disposed, the amount of oxygen in the landfill, moisture content, temperature, and age of the landfill (2). Landfill gas primarily consists of methane and carbon dioxide, with lower concentrations of other chemicals such as nitrogen, oxygen, sulfides, carbon monoxide, ammonia, and non-methane organic compounds [NMOCs, for example, trichloroethylene, benzene, and vinyl chloride] (2). If humans are exposed, these chemicals can affect health through toxicological mechanisms. Some of these chemicals [e.g., hydrogen sulfide, ammonia, benzene] have distinctive odors which can also produce physiologic responses through non-toxicological mechanisms (55). Furthermore, landfill gases affect the global ecosystem through emissions of greenhouse gases, such as methane and carbon dioxide.

Exposures to landfill gases were explicitly hypothesized as the underlying biologically plausible mechanism for health effects in four epidemiological studies (6, 22-24). However, none of these studies could measure actual exposures given the challenges in identifying the primary etiologic exposure of interest in the presence of multiple exposures and lack of historic measures when chronic exposures were of interest. Instead, these and other studies (6, 14, 16, 17, 22-24, 29) used residential proximity as a proxy for exposure. A variety of health outcomes were evaluated in these studies. The results suggest that living near MSWLFs is associated with elevated risks of poor birth outcomes including low birth weight (14, 23) and certain congenital malformations, such as neural tube defects and abdominal wall defects (14, 17); respiratory conditions including bronchitis and shortness of breath (29); site specific cancers of the stomach, liver, and pancreas (22, 24); and experience of malodors (6).

There were many limitations to these studies. Most notable is that none of the studies measured individual exposures from landfill emissions. This is a common limitation of many epidemiologic studies, particularly in environmental epidemiology. However, this should not imply that improvements in exposure assessment will necessarily elucidate the mechanisms through which landfills negatively impact health. Rather, this conceptual model includes alternative mechanisms that can be used to explore the relationships between solid waste facilities and health. Using this model, the research questions are not focused on quantifying risk of specific disease outcomes due to exposures emanating from landfills, but instead are focused on mechanisms that address the conditions that may result in differential burden of exposure (76).

One such mechanism can be explored through the concept of the built environment. To review, the built environment is defined as the buildings, open areas, and infrastructure created and maintained by human action.  Human action in this sense refers to policies and decisions, not just individual behavior. Figure 2.1 illustrates this point through the connection between geographic scale and the built environment. Select examples of this connection include globalization and the effect on plant closings which have transformed many local built environments, federal transportation policies which have influenced interstate road projects and local land use patterns, and local government authority of zoning and land use policies.

Environmental disamenities, such as landfills and toxic release sites, can be considered components of the built environment.  Figure 2.1 illustrates the connection from the built environment to solid waste production. This highlights the point that materials used to construct the built environment result in waste production.  Figure 2.1 also illustrates the feedback between solid waste landfills and the built environment. This depiction highlights the point that the presence of a landfill is part of the built environment that may impact the presence of other components of the built environment. This can be due to the odor, noise, traffic and visual pollution from the landfill that may act as repellents to health promoting amenities, such as health clinics or food stores. This relationship may be influenced by zoning or land use polices that serve to separate noxious uses from beneficial uses or through individual firm location decisions. On the other hand, additional landfills may be attracted to the area for those same reasons. The arrow between the built environment and the landfill emissions represents the potential role the built environment can have on mediating the severity of emissions. For example, the construction and maintenance of roads can influence traffic patterns.

Although not explicitly illustrated as such, the built environment is more than its component pieces. However, the way individuals and social groups interact to shape, maintain, and reproduce the built environment is an important concept that is not fully captured in a one-dimensional model. For example, schools are depicted in the model under the sub-heading buildings to provide an illustration of the built environment and its connection to geographic scale, landfills, health and community susceptibility. However, it is important to note that this label represents more than the ‘bricks and mortar’ used to construct the school building, although the quality and maintenance of the building is clearly influential for health, for example through indoor air exposures that can trigger respiratory conditions and may affect student performance (42). Continuing the school example, the complex relations between geographic scale and the built environment are highlighted. In the United States, school funding is primarily derived from the state and local tax base (63). The local tax base is affected by forces outside the locality, such as the impacts of de-industrialization and suburbanization (5). The quality of schools is a consideration in house prices and community development, which in turn contributes to the local tax base, either positively or negatively. Communities with a weak tax base desperate for increased tax revenue to support local growth, including school construction and funding, have considered landfills as a source of tax revenue (3).

The location of landfills near schools create traffic safety concerns of transportation routes utilized by garbage trucks and school buses (15). If active landfills are located in close proximity to schools, malodors and noise from daily landfill activities may affect the learning environment and student performance. Furthermore, children may be more susceptible to hazardous agents of landfill gases (34). In a survey of 267 North Carolina middle schools, 9% of schools reported odor from landfills outdoors and 3% of schools reported landfill odor inside the school (43). The presence of landfill odor outdoors can reduce opportunities for physical activity for school children during recess. Physical activity is important for cardiovascular health and reducing obesity in children and adults (18). The impact of the built environment on physical activity has received renewed attention (12, 25, 27). For example, the presence of neighborhood walking trails may increase opportunities for physical activity. However, the actual or anticipated presence of malodors from landfills can impede the use of such facilities. Garbage truck traffic may also present safety concerns that may limit cycling or walking.

These limitations may be more detrimental to non-white and low-wealth communities due to increased community susceptibility (21, 35). African-Americans compared to White-Americans (46), and persons of lower socioeconomic status [SES] compared to higher SES (48), have poorer health, higher rates of most diseases, higher mortality, and shorter life expectancies. In addition, these populations may have limited resources to seek other venues for activity, such as a fitness center, due to lack of facilities in close proximity (25) or high cost.

## C. Discussion

The title of this article is meant to invoke images of the scales of justice and spatial scales. This should serve as a reminder that our world is interconnected and that decisions by some groups impact the quality of life for other groups. This is important since solid waste landfill siting decisions are often framed as a local issue. This is effectively done through the use of familiar terms such as locally unwanted land use [LULU] to describe the disamenity. Community opposition to LULU siting decisions have been labeled as ‘NIMBYisms’ [Not in My Backyard] and the opposition’s arguments are discounted as being emotional and selfish (37). The local experience is emphasized, while the connections to other scales where the problem is produced are ignored. As Kurtz (33) states “… the locally experienced problem of burdensome pollution can hardly be resolved at the local scale, whether by capital or the state, when it originates in political and economic relationships that extend well beyond the scale of the locality.”

This model is helpful in relating solid waste landfills to waste production and noting the local scale at which living with solid waste disposal is experienced to national and global scales which promote and maintain conditions for solid waste production. Therefore, potential solutions would entail a multi-level approach to effect policy change. For example, consumers can advocate for national Extended Producer Responsibility [EPR] policies which require corporations to provide reusable or recyclable packaging of their products (57). Since social injustices underlie environmental injustices, policies that serve to improve living conditions, such as living wages, improved access to quality health care, and equitable distribution of school funding, could reduce community susceptibility.

This model was developed to address the relationships between solid waste landfills, environmental injustice and health. While this model is useful in framing research questions, some important challenges to implementing this model should be noted as other researchers consider ways to extend and apply this model to their own work. For example, quantitative methods used to document the burden of potential exposures on communities may be limited by the lack of available data. This may be more salient for research questions related to older facilities when records were not maintained. However, even when records are available, completeness and accuracy of information may be not be guaranteed and records may not be easily obtainable. There are numerous challenges to conducting research involving the concept of community (72). For example, there is no agreed upon definition of community, and many communities can exist simultaneously at various spatial scales. Census geography units are often utilized to proxy communities, in part because they contain readily available information on many demographic and socio-economic characteristics. However, researchers must then rely on census variables which may not adequately represent the underlying constructs of interest.

Despite these challenges, the concepts presented in this model can be used to advance public health inquiry. For example, this model proposes possible relationships between the presence of amenities and disamenities in communities. Future studies could empirically evaluate the relationship between amenities and disamenities by community racial and economic characteristics. The increased availability of tax parcel information in electronic format could assist with this research effort. However, objective measures alone will not provide information regarding how malodor or noise can affect use of the amenities meant to improve health. In addition to quantitative analyses, these studies could also be supplemented with an historical component to address how those amenities and disamenities came to be located in communities and a qualitative component to address questions related to who has access to the amenities and who is burdened by the disamenities. These questions are important when geographic distance to the amenity is small [*e.g.,* miles to nearest healthful food source], but barriers prevent its use by certain populations [*e.g.,* lack of transportation, lack of material resources to purchase food, disrespectful treatment by store employees].

Health is emphasized in this model. Future work could evaluate the aspects of health that have largely been ignored in epidemiological research, including the effect of malodors and noise on quality of life, mental health and well-being. These studies could involve designs that capture information more broadly on health, since current surveillance systems do not routinely collect this type of information [*e.g.* limited use of property due to noise or odor, frequency of headaches, sense of peace and well-being]. This could also involve community participation to increase the extent to which the research meets the needs of the community.

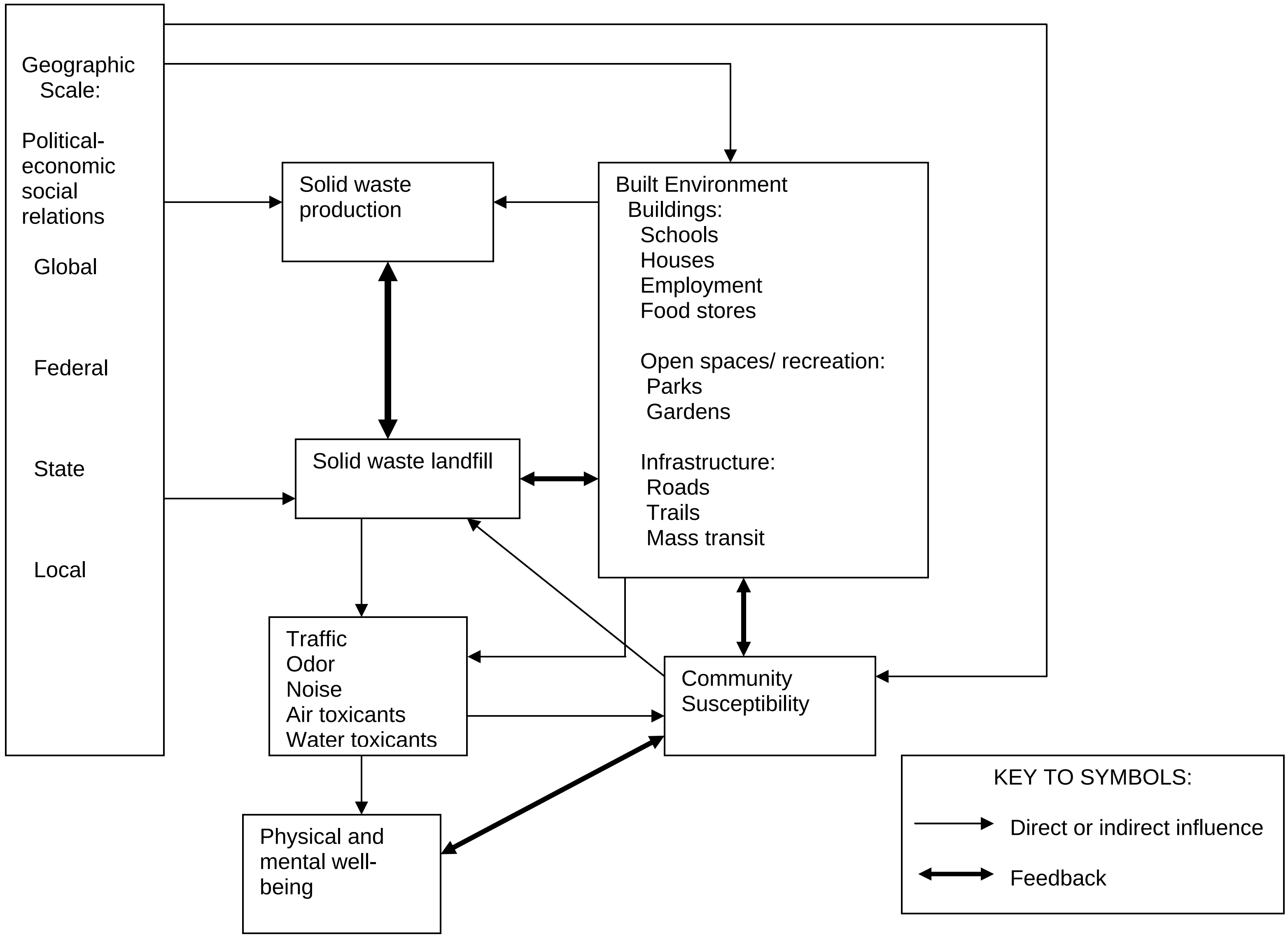


**Figure 2.1: Conceptual Model to Evaluate Solid Waste, Health and Environmental Injustice**

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# CHAPTER 3

# RESEARCH AIMS

## A. Overview

The overall goal of this dissertation research is to evaluate the concerns raised by community groups that solid waste facilities may be disproportionately located in non-white and low-wealth communities in North Carolina. This research will contribute to the research base that can be used to inform public policy decisions and public action. This research provides a statewide analysis of the location of solid waste landfills in North Carolina in relation to race and wealth.

## B. Specific Aims

**Specific aim 1:** Evaluate the prevalence of solid waste facilities in non-white communities compared to white communities and low-wealth communities compared to the high-wealth communities in North Carolina.

The term prevalence is used in epidemiology as a measure of the current burden of disease in the population. A similar conceptualization of prevalence can be applied to this research as the burden of solid waste facilities in the study population at some point in time. This concept of prevalence is operationalized as the proportion of block groups with any permitted solid waste facility on December 31, 2003.

**Specific aim 2**: Evaluate the occurrence of new solid waste facilities in non-white communities compared to white communities and low-wealth communities compared high-wealth communities in North Carolina.

In epidemiology, the term incidence is used to refer to the occurrence of new events in the population over a specified time at risk period. A similar conceptualization can be applied to this research as the occurrence of new permitted solid waste facilities in communities over time. For this research, the concept of occurrence is operationalized as the number of block groups receiving a new permitted solid waste facility over block-group time at risk, where block group-time at risk is defined as January 1, 1990 until time of first permitted solid waste facility, or the end of follow-up on December 31, 2003.

## C. Research questions

### *1. Aim 1 research questions*

#### a. Race and wealth

Community groups in North Carolina have expressed concern that low-wealth communities and communities of color host a disproportionate burden of solid waste facilities. This concern, combined with the lack of readily available data to evaluate these concerns, lead to the formulation of the first two research questions:

1.1a: Is the prevalence of solid waste facilities in non-white communities greater than the prevalence of solid waste facilities in white communities?

1.2a: Is the prevalence of solid waste facilities in low-wealth communities greater than the prevalence of solid waste facilities in high-wealth communities?

### b. Facility type

Solid waste facilities are issued permits based on the types of waste accepted for disposal.

1.1b: Are certain facility types more prevalent in non-white communities compared to white communities?

1.2b: Are certain facility types more prevalent in low-wealth communities compared to high-wealth communities?

## *2. Aim 2 research questions*

### a. Race and wealth

If an association is observed between the presence of solid waste facilities and race and wealth of communities, two possible explanations may be considered. One explanation is that the facilities were sited in these communities. An alternative explanation is that non-white and low-wealth populations moved into the area after the facility was built. In the environmental justice literature, this explanation has been referred to as the 'minority move-in hypothesis' or 'chicken-or-egg question.' To evaluate these possible explanations the following research questions were formulated:

2.1a: Is the occurrence of new solid waste facilities in non-white communities greater than the occurrence of new solid waste facilities in white communities?

2.2a: Is the occurrence of new solid waste facilities in low-wealth communities greater than the occurrence of new solid waste facilities in high-wealth communities?

2.3a: How have the racial and economic characteristics of communities changed after solid waste facilities were sited?

**b. Privatization**

Solid waste management has changed over time and there is a growing trend towards privatization of landfill ownership.

2.1b: Is the occurrence of new privately owned solid waste facilities greater in non-white communities compared to white communities?

2.2b: Is the occurrence of new privately owned solid waste facilities greater in low-wealth communities compared to high-wealth communities?

**c. Waste production**

One aspect of environmental justice is that communities that produce the waste should also deal with the consequences of its disposal.

2.1c: Is the occurrence of municipal solid waste landfills and construction and demolition debris landfills greater in block groups located within counties that produce the most municipal solid waste compared to counties producing less waste?

# CHAPTER 4

# MATERIALS AND METHODS

## A. Overview

This chapter outlines the materials and methods used to conduct a statewide analysis of the location of solid waste facilities among communities in North Carolina. The prevalence of solid waste facilities was examined using a cross-sectional study design. The occurrence of solid waste facilities was examined using a longitudinal design. Data from the US Census Bureau were used to describe communities, defined as populated census block groups based on Census 2000 boundaries. Solid waste facility data were obtained from records maintained by the NC Division of Waste Management. This research was approved by the University of North Carolina Public Health Institutional Review Board [IRB].

## B. Study design

The goal of the first specific aim was to evaluate the current distribution of solid waste facilities among communities in North Carolina. A cross-sectional study design was used to address the first specific aim. The timing of the occurrence of solid waste facilities in relation to race and wealth was the goal of the second aim. A longitudinal design was used to address the second specific aim.

## C. Study population

The study population was comprised of census defined block groups in North Carolina. North Carolina was selected as the setting for this research due to the community concerns raised by citizens of the state and the ability to contribute to a research base used to inform public policy decisions and public action.

To be eligible for inclusion in the study population, the block group must be populated. There were ten block groups in the year 2000 that were not populated. Eight of these reflected areas along the North Carolina coast line that only contained water. One reflected a part of North Carolina State University [NCSU] in Raleigh that did not contain permanent housing in 2000. The other uninhabited block group is located in the central city of Charlotte and is known as the Second Ward or government district. This block group is currently comprised of government buildings, with no housing currently available. However, between 1880 to the 1950's this area was home to the vibrant predominately African-American community called 'Brooklyn' (13). An urban renewal project in the 1960's led to the bulldozing of the buildings and the displacement of residents to public housing. In the 1970's government offices were constructed in its place. There are currently plans to re-develop this area to include mixed-use development, including housing (13). There are 5,261 block groups in the year 2000 that are included as the study population for specific aim one.

For specific aim two, the block group must have been populated in 1990 and 2000. There were thirteen block groups defined according to Census 2000 block group boundaries estimated to have zero population in 1990, nine of which were unpopulated in 2000. One block group was estimated to contain population in 1990, but did not contain population in 2000. This block group represents the area in North Carolina State University. The block groups estimated to have zero population in 1990 but had population in 2000 were in high growth areas near Charlotte, Raleigh, and Durham.

There are a total of 5,257 block groups included in the study population for the second specific aim.

## D. Data sources

### *1. Census block group data*

#### a. United States Census Bureau

This statewide analysis relied on population and socio-economic data collected and disseminated by the United States Census Bureau. Specific aim 1 utilized data solely from the decennial Census 2000. Specific aim 2 utilized data from decennial Census 2000 and 1990. The census data for the decennial Census 1990 was obtained from GeoLytics, described below.

Census data collection: The Census Bureau collects information using two questionnaires; the 'short-form' and 'long-form'. The short form is administered to 100% of the population and includes basic information such as age, gender, race, ethnicity, household tenure, and number of people residing in the household. The long form is administered to a sample of the population, roughly 1 in 6 households. In addition to the basic questions described above, the long form collects information such as educational status, language spoken at home, place of birth, residence five years prior to the census year, employment status, occupation, income in the year previous to the census, year house built, and house value.

Census data dissemination: The Census Bureau tabulates and disseminates data at the aggregate level using Census defined geographic areas. Multiple data files are released corresponding to the data questionnaire. Data from the short form are released in Summary File 1 [SF1]. Data from SF1 are available at the smallest level of Census geography, the census block. Data from the long form are released in Summary File 3 [SF3]. The Census block group is the smallest level for which data from SF3 are released, but for certain cross-tabulations data are only available to the census tract level. Data from SF3 were used in this study.

#### b. GeoLytics

Block group and other Census geography unit boundaries change in decennial Census years. When making comparisons over time, it is important to account for these boundary changes. GeoLytics provides estimates for 1990 demographic variables from the long form, standardized to 2000 Census block group boundaries (10). These estimates were created based on a weighting methodology, and therefore will not exactly match official estimates provided by the US Census Bureau's Census 1990 STF3. Only questions relating to specific aim 2 used data from GeoLytics.

#### c. Linear interpolation

Population estimates at the block group level were only available for decennial Census years 1990 and 2000. Linear interpolation was used to estimate population and wealth characteristics for intercensal years 1991-1999. Linear extrapolation for years 2001-2003 was considered, however, implausible values were obtained for some block groups using this method. Therefore, extrapolation beyond the data was not used. Population and wealth characteristics for years 2001-2003 used the same values as the year 2000.

### *2. Solid waste facility data*

#### a. North Carolina Division of Waste Management

State solid waste laws are codified under Article 9 of the North Carolina public health statute, Chapter 130A. Local governments within the state are responsible for planning for solid waste collection, including provision of recycling services. These waste management decisions may include whether to maintain a solid waste facility in the jurisdiction or to transfer waste out of the area. Many local governments contract with private waste haulers to collect waste. Waste haulers have input in where waste is disposed. Solid waste facility siting decisions are made at the local level.

The North Carolina Department of Environment and Natural Resources [NCDENR], Division of Waste Management [NCDWM] is the agency responsible for the regulation of waste facilities. NCDWM issues permits for new waste facilities, inspects the operation of waste facilities and monitors the results from water and air quality samples submitted by the waste facilities. Records from the NCDWM, Solid Waste Section were used to obtain information for dependent variables.

There are different types of solid waste facilities permitted by NCDWM. Table 4.1 describes the various facility types permitted by NCDWM. Briefly, municipal solid waste landfills [MSWLF] are used for the disposal of garbage generated by residents and businesses. Construction and demolition debris landfills [CDLF] are used for the disposal of building related materials used to construct, demolish and renovate buildings. Waste transfer stations [TRANSFER] are used consolidate waste for transport to a landfill or incinerator for final disposal. Industrial solid waste landfills [INDUS] are used to dispose of non-hazardous solid wastes produced during manufacturing processes and typically consist of a specific waste type generated by a single industry. Tire landfills [TIRELF] are used for the storage of old tires.

<u>Electronic source files:</u> Electronic files listing the permitted solid waste facilities were requested and received from NCDWM in March 2002. The accuracy and completeness of these files were not guaranteed by NCDWM. Only basic information was available in these files, including the permit number, unique facility identifier, facility name, and facility address. However, the majority of facility addresses were not specific enough to map the location of the facilities. These files served as the base information for further development of the source database. Additional information was available from paper records maintained by NCDWM and stored at the Raleigh Central Office.

Methods used to review facility paper records are described in the record review section below.

Geographic files: ArcView shapefiles were obtained from staff at NCDWM. These files contained geographic coordinates in NAD83, State Plane, meters for some facility types. Using software (4) available from the National Oceanic and Atmospheric Administration's [NOAA] National Geodetic Survey [NGS], these coordinates were converted to latitude and longitude coordinates in degree, minute, and decimalized second format. Using an algorithm, these were converted to decimal degree units.

**b. NC Center for Geographic Information Analysis**

Staff at NCDWM referred to the North Carolina Center for Geographic Information Analysis [NCCGIA] as a source of data for locations of landfills. NCDWM staff worked with NCCGIA staff to plot all MSWLF that were active in 1994 on 7.5 minute United States Geological Survey [USGS] topographic maps. The locations were then digitized in Arc/Info in State Plane coordinate system using the North American Datum 27 [NAD27]. In 1998, these data were re-projected to NAD83, State Plane 1983, UTM meters. This file was requested and received from NCCGIA. Using software (3) from NOAA, these coordinates were converted to latitude and longitude coordinates in degree, minute, and decimalized second format. Using an algorithm, these were again converted to decimal degree units.

***3. Solid waste facility record review***

The electronic files received from NCDWM did not contain enough information to answer the research questions. Staff at NCDWM stated that the information on dates of operation, facility size, waste source, and location would be available in facility permit records maintained at the Raleigh Central Office.

Record review commenced May 2004 and ceased November 2004. A research assistant was hired and trained to assist with record review. All information pertaining to the permit, location, size and dates of operation were requested in advance of the appointment. For simplicity of organization, information was requested on a facility by facility basis in alphabetical order of the county. The file room clerks were also asked if there were additional records for facilities that were not part of the initial database.

A data abstraction form was developed for the purpose of record review [see Appendix]. This form contained pre-printed information obtained from the electronic files described above. This method allowed for the verification of existing information. When existing information did not match information discovered during the record review process, the incorrect information was crossed out and the correct information was recorded. In situations when it was not clear which information was correct, NCDWM staff were asked to clarify. NCDWM staff were also contacted after record review ended to provide additional information about certain facilities when information was not found in the records.

Maps, created with ArcView 3.2, were included with each data abstraction form. If coordinates from NCCGIA or NCDWM were available, they were plotted on the map along with major features, such as roads, rivers, and railroads. If coordinates were not available, then the road name of the facility was mapped to provide a general vicinity map. The maps created were compared to maps and other location descriptors found in the solid waste facility record. If the existing coordinate was in the general vicinity [*i.e.,* on the correct side of the road or river] then the existing coordinate was used. If no coordinate was available or if the coordinate did not appear to be in the correct location, then the approximate correct location was marked on the map and the facility was flagged for follow up. Methods for verifying the facility location are described in more detail in the section below.

The amount and quality of information varied for each facility depending on a number of factors such as age and type of the facility. For example, records for land clearing and inert debris [LCID] and yard waste/compost [COMPOST] facilities generally contained less information than records for municipal solid waste landfills [MSWLF]. Generally, there was less information contained in records for MSWLF permitted in the 1970s and early 1980s than more recently permitted MSWLF.

Although solid waste permits are a matter of public record, NCDWM officials limited the amount of time that we were allowed to review the records on a daily and weekly basis due to staffing limitations at NCDWM. This time restriction combined with the lack of complete information for certain facility types resulted in a decision to prioritize the types of facilities that would be reviewed.

Information on the facility type come from NCDWM. It should be noted that these classifications have evolved over the regulatory life of NCDWM, and some overlap may exist for certain types of wastes. For example, a MSWLF may accept construction and demolition waste, but a CDLF cannot accept municipal solid waste. The facility type was based on information contained in the solid waste permit. An intent-to-treat approach was used when the types of waste the facility was originally permitted to accept did not match the types of waste the facility accepted after permitting. For example, one landfill in Mecklenburg County was permitted as a lined, MSWLF. However, this facility only accepts construction and demolition debris wastes. For the purpose of this research project, the facility was classified as a MSWLF since it was originally permitted as such.

The initial research proposal called for reviewing facility records for all landfill types except household hazardous waste storage areas, medical incinerators, and treatment and processing facilities. However, due to the time restrictions noted above and the lack of complete information for certain facility types, inclusion criteria were established. Table 4.1 provides a list of all facility types and the types of waste managed, by inclusion status.

Priority facilities: Priority facility types were identified as those facilities most related to municipal solid waste production, such as MSWLF, CDLF, and TRANSFER. Industrial solid waste landfills were also identified as a priority facility type since industrial solid waste would most likely be disposed in MSWLF if the waste was not disposed in INDUS. Tires are prohibited from MSWLF, and the bulk storage of tires presents health and safety concerns related to source of vectors from standing water and risk of fire related air pollutants. The available records for all priority facility types were reviewed.

Non-priority facilities: Non-priority facility types are defined as those facilities that were of interest, but due to lack of complete information in the facility records and time constraints, the records were not reviewed. Non-priority types are LCID, COMPOST, and INCIN. Non-priority facility records were only reviewed if they were at the same site as a priority facility as a method to gather more information about the priority facility of interest. Non-priority facilities are not included in the analysis.

Excluded facilities: Excluded permitted facility types are HHW, INCIN-M, TP, MWP. Pre-regulatory landfills that did not receive a permit from NCDWM were also excluded. Although these facilities present public health and environmental concerns to communities, a complete list of these facilities does not exist.

### *4. Verifying solid waste facility location*

The goal of this research is to evaluate the location of solid waste facilities in communities in North Carolina. Therefore, it was important to obtain good information about the location of each facility. One method that can be used to verify the facility location is to personally visit each facility and obtain a spatial coordinate using a global positioning system [GPS]. In this systematic statewide study the cost and time to travel to each facility was prohibitive. Another method often used to assign a spatial coordinate is address matching. Address matching was not considered to be a useful method in this study due to the lack of complete street address information available for facilities.

The web-based program TerraFly® (1) was used to obtain spatial coordinates for facilities that did not have coordinates or had incorrect coordinates from other sources. TerraFly contains aerial photographs and satellite imagery that can be accessed by entering the coordinates or address of any location. The user can virtually 'fly' over these images and obtain a latitude and longitude coordinate at the point of interest. A protocol was developed to determine the facility location using TerraFly. Two research assistants were hired and trained to assist with this task. Maps photocopied from the facility record, maps used in the record review process, and available on-line tax parcel maps were used as reference points during the TerraFly process. Solid waste landfills have features that are identifiable on aerial photographs, such as higher topography than adjacent land uses, large tracts of cleared land typically bordered by trees, and if inactive, are covered with grass. When the facility was identified in TerraFly the latitude and longitude coordinate that most closely reflected the approximate center of the area used for waste disposal was recorded and used as the final coordinate.

The source of final coordinates came from NCCGIA, NCDWM staff, or TerraFly for 417 of the 419 priority facilities. For two facilities [one closed MSWLF and one closed INDUS] the locations could not be verified despite consultation with numerous NCDWM staff and county officials. Block group identifiers were assigned to these facilities based on the location of the reported facility road name. The block group centroids were used as the final coordinates for these facilities.

### *5. Estimating permit dates*

The analysis of specific aim two requires information on the timing of the solid waste facility event. It was preferable to use the date the siting decision was made for each facility as the facility event date. However, this decision is made at the local level and it was not possible determine this date for all facilities. Once local government approval is granted for the solid waste facility, a permit application is prepared and submitted to NCDWM. NCDWM reviews the permit application and issues permits to owner/operators of facilities. The date NCDWM issued a permit to construct to the facility is used as the event date. Not all facilities require a permit to construct. In those cases, the permit to operate date was used. When an exact date was not found in the facility records, this date was estimated. Dates were estimated only for facilities issued a permit to construct and permit to operate between 1990 and 2003. When only the month and year were known, the day was estimated as the 15th. For one facility the permit year was estimated using information on the date of closure and the permit date of other facilities at the site, and the midpoint of this year was assigned as the permit date.

For facilities that were issued a permit to construct and permit to operate [or letter of approval] before 1990 it was not necessary to estimate the exact date when dates were missing. These facilities were coded as receiving a permit before January 1, 1990.

**E. Data entry**

A data entry system was created to facilitate electronic recordation of solid waste facility information abstracted from NCDWM records. Visual FoxPro® software was used to create the data entry system (15). The electronic information obtained from NCDWM and NCCGIA was used as a base for this data entry system. In addition, variables were created to correspond to the information recorded on the data abstraction form. This system also allowed for the addition of facilities based on records found in the NCDWM file room that were not reflected in the electronic files received from NCDWM. Changes made to existing information were recorded and tracked in this system. The data entered into the system were imported into SAS for data checks and for analysis.

## F. Geographic Information System [GIS]

### *1. Data sources, map boundary layers*

Census block group boundaries, block boundaries, county boundaries, and urbanized area/urban cluster boundaries based on the year 2000 Census were obtained in shapefile format from the ESRI website (6). The ESRI shapefiles for the US major roads for the state of North Carolina were obtained from the University of North Carolina at Chapel Hill GIS library.

The Census block group boundary layer did not account for the large bodies of water in coastal eastern North Carolina [*e.g.,* Albemarle Sound and Pamlico Sound]. For visual purposes, and to be sure that solid waste facility locations were assigned to block group land area, the block group file was modified to erase the major water areas. These water areas were identified by information contained in the US Census Summary File 1, at the Census block level. Using ArcGIS version 9.1 (7), blocks that completely represented water areas were overlayed with the block group boundary layer. The Analysis Tools / Overlay / Erase tool was used to create a block group file that contained block group boundaries without the major water bodies.

### *2. Geocoding solid waste facilities to block groups*

A file containing the solid waste facilities that met the inclusion criteria outlined above was imported to ArcGIS 9.1. This file was added as a layer using the final latitude and longitude coordinates as described earlier. The points were overlayed with the census block group shapefile and the block group codes were joined to the solid waste facility data file. This census shapefile only contained the block group geographic identifiers. The solid waste facility file containing the block group identifier was imported into SAS version 8.2.

### *3. Calculating distance from block group*

Variables representing the proximity to major roads and urban centers were created using the Analysis / Proximity / Near tool in ArcGIS 9.1. Prior to performing the distance calculations, all layers were converted to the State Plane coordinate system, North American Datum 1983 [NAD83] in meters and projected using the Lambert conformal conic projection. The distance from the block group centroid was used to calculate distances to nearest roads and urban areas. The centroid of the urbanized area/urban center [UAUC] was approximated using the coordinate for the Census Designated Place [CDP] that represents the core of the UAUC. When the CDP coordinate was not available, the centroid of the block that most closely reflected the center of the UAUC was used.

## G. Creation of analytic files

### *1. Solid waste facility inclusion criteria*

In addition to the inclusion criteria for record review described above, other criteria for inclusion into the analysis databases include the following:

- Facility must have received a permit from NCDWM
- Facility must have been issued permit to operate [or equivalent] by December 31, 2003
- Facility type is MSWLF, CDLF, TRANSFER, INDUS, or TIRELF

### *2. Block group files with solid waste facility data*

Solid waste facilities that met the above inclusion criteria were geocoded to a census block group, as described in the GIS section above. After all facilities had a unique block group identifier, sums of the number of facilities, facility type, operation status, and number of sites were computed for each block group to create a file with one observation per block group. For specific aim one, this information was summarized to describe the solid waste facility presence [*i.e.,* the block group contains one or more solid waste facilities] or absence [*i.e.,* the block group does not contain any solid waste facilities]. This file was then merged with the full block group census data containing the demographic information.

For the second specific aim, two main analytic files were created. One file considered the occurrence of solid waste facilities in block groups between 1990-2003 only if the block group did not contain a solid waste facility on January 1, 1990. This type of analysis is analogous to epidemiological methods that consider incidence of disease or injury among individuals that are disease or injury free at the start of the follow-up. Block groups contributed ‘block group time’ until the date the first permit was issued between January 1, 1990 and December 31, 2003, or until December 31, 2003 if no solid waste facility permit was issued.

A second file was created that considered block groups with any previous solid waste facility. This file was based on block groups that had a solid waste facility on January 1, 1990. If a block group did not contain a solid waste facility on January 1, 1990, but received at least one between January 1, 1990, the block group was added to this file on the date the first permit was issued. Block groups contributed ‘block group time’ until the date the first permit was issued or until December 31, 2003.

## H. Variable selection

The variable selection was based partly on the conceptual model described in Chapter 2 and partly on previous environmental injustice studies.

### *1. Independent variables*

Issues of race and class relations underlie the concerns of environmental injustice and thus are the primary explanatory variables. Other covariates of interest were population density, region of the state, proximity to major highways, and proximity to urban centers. The rationale for these variables is provided below. Measures used to quantify these variables are provided in Table 4.2.

### a. Primary variables

The primary variables of interest are race and wealth. Race and wealth were not entered into models as competing predictors, but their interaction was assessed. In addition to race and wealth, another conceptually important primary variable is waste production.

<u>Racial composition:</u> Race is a socially constructed concept (17). In this research, the concept of race/ethnicity was simplified to white or non-white. For the year 2000, white is defined as the percent of the population who reported only one race as white and who were not of Hispanic ethnicity. Non-white is defined as all other responses. Reporting more than one race was a new aspect of the Census 2000. In 1990, respondents could select only one race.

<u>Community wealth:</u> Wealth was used as an indicator of class since wealth is a determinant of social class in the United States (12). Wealth goes beyond annual income to incorporate overall net worth, including possessions, stocks/bonds, savings, and inheritance. Unfortunately, good measures of wealth are not currently available from the US Census Bureau decennial census. This research used median house value as a measure of community wealth. Median house value has been used as an indicator of community wealth (16) and as a proxy for land values (20). Block group median house value is correlated with block group percent of persons below poverty [r= -0.4], which has been used in other environmental justice research.

Research questions related to specific aim 1 used the median house value for all owner-occupied housing units. This variable is created by the US Census Bureau based on responses to a question on the 'long form' questionnaire which asks respondents to report how much their property [house, condominium or mobile home, and lot] would sell for, if it were for sale (21). Respondents are provided with twenty-four check box options to report their estimate. The US Census Bureau calculates the median value, rounded to the nearest one hundred dollars.

For research questions related to specific aim 2, the median house value for specified owner-occupied housing units was used. This variable is also created by the Census Bureau, but includes only single family housing units on less than ten acres of land without a business office on the property. Mobile homes are excluded. Only the median value for specified units was available from GeoLytics. To account for inflation between 1990 and 2000, the median house value in 1990 was adjusted to 2000 dollars using the inflation factor of 1.277636 (22). In the year 2000, the correlation between block group median house value for owner-occupied housing units and block group median house value for specified owner-occupied housing units was 0.94.

<u>Solid waste production:</u> Solid waste facilities are deemed necessary as a method to manage the millions of tons of waste produced annually in the United States. An important consideration, that has not previously been addressed, is the relationship between location of solid waste disposal facilities and location of solid waste production. Unfortunately, a measure of solid waste production does not exist. However, NCDWM reports the tons of municipal solid waste and construction and demolition debris waste that is legally disposed anywhere by county of origin. These estimates are available for fiscal years 1991-2004. These estimates are provided to NCDWM by solid waste facility operators. Population size of the county is highly correlated with annual tons of waste disposed in the county’s name, therefore, per capita waste was used. The annual estimates can vary and it is difficult to know if these fluctuations represent real changes or reporting differences. Furthermore, while the annual estimates for individual counties can vary, there was a fairly consistent ranking of counties across all years [*i.e.,* counties typically remained among the highest, middle or lowest counties across all years].

Therefore, to obtain a more stable estimate of waste disposed per person by county of origin, the cumulative average tons for 1991-2004 divided by county population estimates from 1991-2004 was used to compute an average waste disposed per person for each county. Block groups were assigned the value of the county in which they were located.

### b. Covariates

Alternative explanations for solid waste facility locations that are related to the primary variables of interest were also examined.

Population density: Solid waste landfills require land, which is more plentiful in areas with low population density. Population density is measured as persons per square mile. In North Carolina, the western Appalachian mountain region is less densely populated and contains many areas of poverty. The eastern coastal plain and mainland tidewater regions, included in the 'Black Belt' are also less densely population and contain areas of poverty.

Proximity to highways: Transportation networks are an important consideration in any facility location decision (5). Highway density was shown to be positively associated with municipal solid waste landfill location in Ohio counties (2). Since trucks transport waste to landfills, the proximity to a major highway, such as an interstate or US highway, may be an important consideration in landfill siting. The GIS section below describes how this variable was created.

Proximity to nearest urban center: Population size is a strong determinant of waste production. Under current waste management practices waste can travel far distances between the point where it is produced and the point where it is disposed. The GIS section below describes how this variable was created.

Region: The physical and social geography of North Carolina is broadly characterized by four primary regions, from west to east: Mountain, Piedmont, Coastal

Plain, and Tidewater (9). Figure 4.1 illustrates the location of these regions and Table 4.3 describes the average percent non-white population, median house values, and population density for block groups in these regions.

A brief description of each of these regions is provided as introductory background. These descriptions are based on a reading of Gade *et al*. (8) and analysis of US Census data.

*Mountains*: The Appalachian Mountains form the western border of North Carolina. The Mountain region is the least densely populated of the regions in the state. The region is predominately white, although there is a Native American presence, many of whom reside on or near the Cherokee Indian Reservation. Although areas of persistent poverty that have plagued the Appalachian region remain, this region has seen population growth in recent years in the form of retirees and expensive vacation homes.

*Piedmont:* The Piedmont is the most densely populated region, reflecting the location of the major urban areas in the state: Charlotte, Raleigh, Greensboro, Durham, and Winston-Salem. The majority of North Carolinians reside in the Piedmont, including the majority of African-American residents who reside in the urban centers of the Piedmont. Compared to other regions, the Piedmont is wealthy, due in part to manufacturing centers and the development of high-tech research corridor (11).

*Coastal Plain:* The Coastal Plain has been the agricultural center of North Carolina. This region has the largest proportion of non-white residents of the regions in the state, including a large Lumbee Indian population in Robeson County, and African-American population which is part of the US 'Black Belt' region. The African-American population in the Coastal Plain is largely rural. This region is less wealthy than other regions of the state, and has not benefited from the economic boom that other regions of NC and the US South have experienced.

*Tidewater*: The Atlantic Ocean forms the eastern border of North Carolina. Barrier islands, known as the Outer Banks, separate the ocean from sounds. Rapid growth and development of expensive beach homes has occurred along this ecologically sensitive region, adding to the increased population density and relatively higher median house values in this area.

<u>Presence of solid waste facility in block group before 1990:</u> Solid waste facilities are often permitted at the site of a previous solid waste facility. Many solid waste facilities issued permits between 1990-2003 were located at sites that formerly were used for disposal of municipal solid waste. For specific aim 2, it was necessary to account for this phenomenon when evaluating the effect of race and wealth on new facility permitting.

### *2. Dependent variables*

Information abstracted from the Division of Waste Management were used to create the dependent variables.

#### a. Aim 1

For specific aim one, the following dependent variables were defined:

<u>Presence of any solid waste facility</u>: Presence or absence of any priority solid waste facility in the community was used as the measure of community solid waste facility prevalence. Presence of a solid waste facility is defined according to the spatial coincidence method. [ANY=1 if present, 0 if not]

<u>Presence of any MSWLF:</u> Presence or absence of any municipal solid waste landfill in the community was used as the measure of community MSWLF prevalence. [ANYMSW=1 if present, 0 if not]

<u>Presence of any CDLF:</u> Presence or absence of any construction and demolition debris landfill in the community was used as the measure of community CDLF prevalence. [ANYCD=1 if present, 0 if not]

Presence of any TRANSFER: Presence or absence of any solid waste transfer station in the community was used as the measure of community TRANSFER prevalence. [ANYTR=1 if present, 0 if not]

Presence of any INDUS: Presence or absence of any industrial solid waste landfill in the community was used as the measure of community INDUS prevalence. [ANYIN=1 if present, 0 of not]

#### b. Aim 2

For specific aim two, the following dependent variables were used:

Occurrence of any solid waste facility, 1990-2003: Occurrence or non-occurrence of any solid waste facility issued a permit to construct between January 1, 1990 and December 31, 2003. [ANY9003=1 if occurred, 0 if not]

Time to solid waste facility event: The time from entry into study until date the first permit was issued to a solid waste facility in the block group between January 1, 1990 and December 31, 2003, or December 31, 2003 if no permitted solid waste facility was issued.

## I. Statistical analysis

### *1. Overview*

The major goals of the statistical analysis were to evaluate the effect of block group race and wealth on the prevalence and occurrence of solid waste facilities. Statistical analysis was performed using SAS software version 8.2 (18) and SAS software version 9.1.3 (19). The statistical analysis began with an examination of the univariate distributions of independent and dependent variables. Independent variables based on percentages of population or housing characteristics were grouped into categories representing five percent increments. Independent variables based on distances were grouped in one mile increments. To assess the bivariate relationship between the presence of any solid waste facility and block group characteristics, plots were created and summary measures were computed for each independent variable. Independent variables were entered as continuous variables in a model to predict the outcome. If the linearity assumption was not met, higher order terms or indicator variables were used to specify the variables. Multivariable models were created by fitting a baseline model consisting of the covariates. Once the covariates only model was determined, the primary variables [race or wealth] were entered.

### 2. *Statistical model Aim1*

The relationship between race and wealth of block groups and the presence of any solid waste facility was assessed using logistic regression. To account for the nesting of block groups within counties, generalized estimating equations [GEE] specifying the exchangeable working correlation matrix were used. The analysis was performed using the SAS GENMOD procedure using a logit link and binomial residual distribution (18). For example, the final model used to assess the effect of race on the prevalence odds of any solid waste facility, adjusting for population density and region was specified as:

$$Logit\{PR[ANY=1]\} = \beta 0 + \beta 1 * INDPNW20 + \beta 2 * INDPNW30 + \beta 3 * INDPNW50 + \beta 4 * INDPNW100 + \beta 5 * LNPOPDEN + \beta 6 * LNPDSQ + \beta 7 * LNPDCU + \beta 8 * INDREGM + \beta 9 * INDREGC + \beta 10 * INDREGT$$

Similar model specification was used to assess wealth, substituting the indicator variables for race with the indicator variables for wealth. When facility type was evaluated, the left-hand side of the equation was specified as logit{Pr[ANY'TYPE'=1]}, where the 'type' refers to the facility type.

Race and wealth were not entered into statistical models as competing predictors. However, the joint contribution of block group race and wealth on the prevalence of any solid waste facility was of interest. To assess the interaction between race and wealth, categories were collapsed. The percent non-white population variable was defined as <10%; 10<30% and ≥30% . Median house values were defined as <$60,000; $60,000<100,000 and ≥ $100,000. The model was specified as:

$$
\begin{aligned}
&Logit\{PR[ANY = 1]\} = \beta 0 + \beta 1 * INDPNW1030 + \beta 2 * INDPNW30100 + \\
&\beta 3 * INDW060 + \beta 4 * INDW60100 + \beta 5 * [INDPNW1030 * INDW060] + \\
&\beta 6 * [INPNW30100 * INDW60100] + \beta 7 * [INDPNW30100 * INDW060] + \\
&\beta 8 * [INDPNW30100 * INDW60100] + \beta 9 * LNPOPDEN + \beta 10 * LNPDSQ + \\
&\beta 11 * LNPDCU + \beta 12 * INDREGM + \beta 13 * INDREGC + \beta 14 * INDREGT
\end{aligned}
$$

### *3. Statistical model Aim 2*

The relationship between race and wealth of block groups and the time to occurrence of any solid waste facility was assessed using the extended Cox proportional hazard regression. The extended model was used to account for the time-varying variables: percent non-white, median house value, and population density. Time varying-variables were set to change values on April 1 of the year to be consistent with the date of the decennial Census. To account for the nesting of block groups within counties, the robust sandwich variance estimate was used. The analysis was conducted using the SAS PHREG procedure (19). However, since much of the complex computation involved with estimating the effects goes on ‘behind the scenes,’ additional models were run via ungrouped Poisson regression models, adjusted for calendar year, using the SAS GENMOD procedure to ensure that the resultant hazard ratios were plausible (14).

**Table 4.1: Types of solid waste facilities and examples of waste managed, by inclusion status**

| Facility Type | Abbreviation | Examples of wastes managed |
|---|---|---|
| ***PRIORITY*** | | |
| Municipal Solid Waste Landfill | MSWLF | 'Garbage' [package wrapping, paper, food scraps], sludge |
| Construction and Demolition Debris Landfill | CDLF | Concrete, wood [from buildings], asphalt, roof shingles, gypsum wallboard [sheetrock/drywall], plumbing and electrical fixtures |
| Waste Transfer Station | TRANSFER | 'Garbage', construction and demolition material |
| Industrial Solid Waste Landfill | INDUS | Non-hazardous wastes generated by industries, including sludge from pulp paper processing and ash from power generation |
| Tire Landfill | TIRELF | Tires |
| ***NON-PRIORITY*** | | |
| Land Clearing and Inert Debris Landfill | LCID | Land clearing waste including concrete, untreated wood, gravel, rock, and brick |
| Yard Waste / Solid Waste Compost Facility | COMPOST | Yard wastes include grass clippings, tree limbs and other landscaping materials. Compost Facilities utilize a controlled biologic process to degrade non-hazardous solid wastes |
| Incinerator | INCIN | 'Garbage' |
| Incinerator- Industrial | INCIN-I | Industrial solid waste [non-hazardous] |
| ***EXCLUDED*** | | |
| Incinerator- Medical | INCIN-M | Medical wastes |
| Treatment & Processing | TP | Purtrescible solid wastes that will be landfilled, reclaimed or recycled |
| Waste Sorting / Mixed Waste Processing | MWP | 'Garbage'; recyclable materials are sorted from garbage |
| Household Hazardous Waste | HHW | Household cleaners, pool chemicals, automotive chemicals, paint |

**Table 4.2: Coding of independent variables[1], aim 1**

| Description | Variable Name | Coding |
|---|---|---|
| **Race** | *PNWNHA*[2] | Continuous [range 0 to 100], used to create indicator variables: |
| Percent non-white population | INDPNW20 | 1 if 10<=pnwnha<20; else 0 |
| | INDPNW30 | 1 if 20<=pnwnha<30; else 0 |
| | INDPNW50 | 1 if 30<=pnwnha<50; else 0 |
| | INDPNW100 | 1 if 50<=pnwnha<=100; else 0 |
| | | referent group is 0<10% non-white |
| **Wealth** | *T_MEDHVA* | Continuous [range $0 to 804,600], used to create indicator variables: |
| Median house value of all owner-occupied housing units | INDWLOW | 1 if 0<=t_medhva< 60000; else 0 |
| | INDWMEDL | 1 if 60000<=t_medhva< 75000; else 0 |
| | INDWMEDH | 1 if 75000<=t_medhva<100000; else 0 |
| | | referent group is median house values >=$100,000 |
| **Population density** | lnpopden | Natural log of population density |
| Persons per block group square mile [land area only] | lnpdsq | Natural log of population density, squared |
| | lnpdcu | Natural log of population density, cubed |
| **Region** | *Region_name* | Text, name of region, used to create indicator variables: |
| Geographic region of the state | indregm | 1 if region_name = Mountain; else 0 |
| | indregc | 1 if region_name = Coastal Plain; else 0 |
| | indregt | 1 if region_name = Tidewater; else 0 |
| | | referent group is Piedmont |
| **Distance to nearest urban center** | *Near_uauc_mi* | Continuous [range<0.1 to 51 mi], used to create indicator variables: |
| Distance from block group centroid to centroid of nearest urbanized area or urban cluster, in miles | uauc3 | 1 if greater than or equal to 3 miles; else 0 |
| **Distance to nearest road** | *Near_int_mi* | Continuous [range <0.1 to 137 mi]; used to create indicator variables |
| Distance from block group centroid to nearest interstate or US highway road segment, in miles | *Near_us_mi* | Continuous [range <0.1 to 27 mi]; used to create indicator variables |
| | indrd1 | 1 if near_int_mi <10 OR near_int_mi< 1; else 0 |
| | indrd2 | 1 if near_int_mi ≥ 10 AND near_us_mi ≥1; else 0 |
| | | referent group is <10 miles from interstate and <1 mile from US hwy |

1. US Census Bureau Census 2000, SF3 used for demographic and wealth variables; 2. Variable names in italics presented for clarification purposes only, these variables were not included in statistical models.

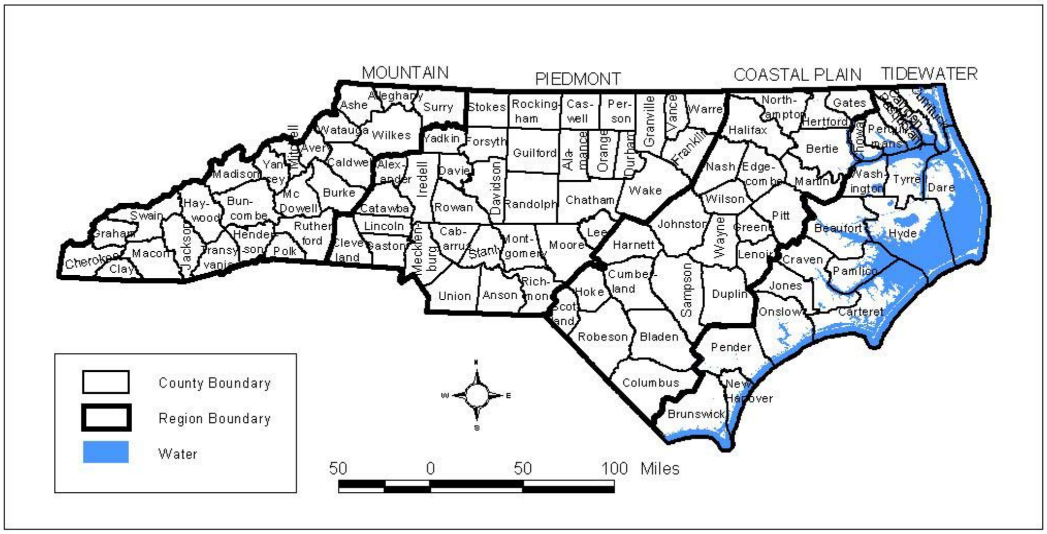


**Figure 4.1: North Carolina counties and regions**

**Table 4.3: Description of block groups in North Carolina regions, 2000**

| Region name | Total population | Number of block groups | Mean block group percent non-white | Mean block group median house value | Mean block group population density |
|---|---|---|---|---|---|
| Mountain | 1,070,643 | 835 | 10.0 | $92,292 | 550 |
| Piedmont | 4,589,445 | 2,826 | 30.5 | $110,485 | 1,501 |
| Coastal Plain | 1,605,715 | 1,087 | 47.6 | $71,336 | 935 |
| Tidewater | 783,510 | 513 | 28.0 | $99,412 | 1,031 |
| North Carolina | 8,049,313 | 5,261 | 30.5 | $98,429 | 1,187 |

Source: US Census Bureau, Census 2000 SF3. Median house value for all owner-occupied housing units

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# CHAPTER 5

## RESULTS AIM 1:

## RACE, WEALTH, AND PREVALENCE OF SOLID WASTE FACILITIES IN NORTH CAROLINA, 2003

### A. Introduction

Environmental injustice refers to the disproportionate burden of harmful by-products created through the production and consumption of material goods, on non-white and low-wealth populations (18). Environmental injustice was first brought to the national spotlight in 1982 when residents in predominately African-American and low-wealth Warren County, North Carolina protested the state's decision to site a hazardous waste landfill in their community (4). This landfill would accept soil contaminated with polychlorinated biphenyls [PCBs] that had been illegally dumped along 210 miles of North Carolina roadways. While the efforts to stop this hazardous waste landfill from being built in the community were not successful, this event sparked the national environmental justice movement (26). Since then, numerous research studies have been conducted to evaluate the relationship between race, class and a variety of environmental hazards at various locations across the United States and globally. With few exceptions (9, 12), environmental injustice concerns related to solid waste facilities have not been examined.

As discussed in Chapter 2, environmental injustice and solid waste are public health issues. Proper solid waste management has long been a public health concern. Many facilities that were formerly used for municipal solid waste disposal are now a source of groundwater contamination (22, 30). Landfills are also a source of odorous and non-odorous gases (2). One mechanism through which landfills can affect health is through direct exposure to harmful toxicants found in landfill gases. Several epidemiological studies have evaluated this hypothesized pathway using residential proximity to landfills as a proxy for exposure. The results of these studies suggest that living near municipal solid waste landfills is associated with elevated risks of poor birth outcomes including low birth weight (5, 14); respiratory conditions including bronchitis and shortness of breath (17); site specific cancers of the stomach, liver, and pancreas (13, 15); and experience of malodors (3).

Another mechanism through which solid waste landfills can affect health is through the built environment. The built environment refers to buildings, open areas, and infrastructure created and maintained by human action. Residents living in close proximity to active landfills and transfer stations may be impacted by noise exposures from daily activities at the facility. Noise exposures can affect well-being and induce stress (23). Trucks transporting waste present traffic safety concerns (8). Odor, noise, traffic and visual pollution from landfills may act as repellents to health promoting amenities in communities, such as health clinics or food stores, or may limit opportunities for physical activity.

Recent proposals to build landfills in North Carolina have generated concerns that the state will become a major importer of wastes produced in other states (16, 25). Citizens of North Carolina have expressed concern that non-white and low-wealth communities may currently host a disproportionate burden of solid waste facilities. To date, however, the location of solid waste facilities in relation to community race and wealth has not been evaluated on a statewide level in North Carolina. This study was conducted to evaluate the prevalence of solid waste facilities in non-white communities compared to white communities, and low-wealth communities compared to high-wealth communities.

## B. Materials and methods

The North Carolina Division of Waste Management [NCDWM] is responsible for permitting solid waste facilities in the state. Electronic files of permitted solid waste facilities were obtained from NCDWM in 2002. These files lacked information necessary to address the study aims, including dates of operation and specific facility location. Additional information was obtained through a systematic review of solid waste facility records maintained by NCDWM. For the purpose of this study, solid waste facilities were defined as municipal solid waste landfills [MSWLF], construction and demolition debris landfills [CDLF], industrial solid waste landfills [INDUS], tire landfills [TIRELF] and waste transfer stations [TRANSFER]. Solid waste facilities issued a permit to operate [or equivalent] by December 31, 2003 were included in the study.

Geographic coordinates were used to locate solid waste facilities within block groups. The North Carolina Center for Geographic Information Analysis [NCCGIA] provided geographic coordinates for some solid waste facilities. Complete addresses were not available for most solid waste facilities, therefore address matching could not be used to locate facilities. The internet program TerraFly® (1) was used to obtain latitude and longitude coordinates for facilities and to verify coordinates received from NCDWM and NCCGIA. Maps obtained during the facility record review and tax parcel maps available through county websites guided the TerraFly process. Briefly, this process involved entering an address or geographic coordinate into the TerraFly website interface and 'virtually' flying over aerial images until the solid waste facility was located. The latitude and longitude coordinates for the point that approximated the center of the facility were recorded. Geographic coordinates were not available for two solid waste facilities. The coordinates for these facilities were assigned to the centroid coordinates of the census block group that contained the road listed as the facility address.

Communities in North Carolina are the conceptual basis for the study population. Inhabited census block groups were used as the unit of analysis to define communities [n=5,261]. Census block groups are designed to contain between 600 and 3,000 people, with an optimum size of 1,500 people (28). Block group level race, median house value and population density were obtained from the United States Census Bureau decennial Census 2000 Summary File 3 (29). Census 2000 geographic boundary files were obtained from ESRI (6). Geographic coordinates of solid waste facilities were spatially joined to census block groups using ArcGIS version 9.1 (7).

The prevalence of solid waste facilities was defined as the presence of any solid waste facility in the block group as of December 31, 2003. Indicator variables were used to represent higher percent non-white block groups compared to the lowest and lower wealth block groups compared to the highest. Percent non-white was defined as the percent of the total block group residents that did not self report race/ethnicity as white, non-Hispanic alone. Median house value of all owner-occupied housing units in the block group was used as an indicator of community wealth. Percent non-white and median house value were not entered into models as competing predictors, but their interaction was assessed. Landfills require land for waste disposal which is more plentiful in less densely populated areas. Therefore, population density [persons per square mile] was included; fit with cubic polynomial terms of the natural log of block group population density. The physical and social geography of the state of North Carolina is described by four regions [from west to east]; Mountain, Piedmont, Coastal Plain, and Tidewater (11). Indicator variables were used to account for region, using Piedmont as the referent category. Block group distance to nearest major road and distance to nearest urban area were considered as alternative explanations for the relationship between race, wealth and prevalence of solid waste facilities. However, once population density was accounted for, distance to roads and distance to urban area were not strongly related to location of solid waste facilities. To achieve a parsimonious model, only population density and region were included as covariates when assessing the effect race and wealth on prevalence of solid waste facilities.

Logistic regression was used to compute crude and adjusted prevalence odds ratios, using the generalized estimating equation method to account for the nesting of block groups within counties. These analyses were computed using the SAS GENMOD procedure (27).

## C. Results

Table 5.1 describes the mean block group population density by race and wealth for North Carolina and regions. On average, non-white block groups are more densely populated than white block groups [less than 10% non-white]. This pattern is consistent for all regions, although white block groups in the Coastal Plain are more densely populated than white block groups in other regions. The Piedmont region is the most densely populated region, reflecting the location of major population centers in the state such as Charlotte, Raleigh, Durham and Greensboro. There is less variation in population density based on community wealth. On average, medium-wealth block groups are less densely populated than low-wealth and high-wealth block groups. Figures 5.1 and 5.2 illustrate the spatial distribution of the percent non-white and median house value, respectively, for block groups in North Carolina.

A total of 419 solid waste facilities were eligible to be included in the study. The number, type, operation status, permit date, and owner/operator are provided in Table 5.2. Municipal solid waste landfills [MSWLF] comprise the largest solid waste facility category [48%], with most of these consisting of unlined, closed facilities [158/201, 79%]. Similar to national trends (31), the number of MSWLF in North Carolina that actively accept waste for disposal has decreased since 1990. While these facilities closed, CDLF and TRANSFER stations were permitted [Figure 5.3]. Most solid waste facilities are publicly owned and operated by local governments, reflecting the 20$^{th}$ century trend of solid waste management as a public good provision (24). Nearly all of the industrial solid waste landfills are privately owned and operated, reflecting the use of these facilities for industrial solid wastes generated through manufacturing processes. More recently, the vertical integration of the waste management industry has resulted in privately owned and operated solid waste facilities or public-private partnerships. Figure 5.4 shows the location of the permitted solid waste facilities included in this study.

Table 5.3 provides the crude prevalence and prevalence odds ratios for solid waste facility types by race and wealth. Due to the small number of TIRELF, results are not provided separately for these facilities. There are 251 block groups [4.8%] that contain at least one solid waste facility as defined in this study. Ninety-seven of the 100 North Carolina counties had at least one solid waste facility. MSWLF have the highest overall prevalence [3.2%], followed by TRANSFER [1.6%], CDLF [1.4%] and INDUS [0.8%]. With the exception of INDUS, non-white block groups have higher prevalence of solid waste facilities compared to white block groups. Compared to high-wealth block groups [median house values equal to or greater than $100,000], the crude prevalence of solid waste facilities is higher in lower-wealth block groups. This pattern is generally consistent across facility types. It should be noted that within the highest wealth category, there are only 3 block groups out of 257 [1%] with median house values greater than or equal to $200,000 that contain any solid waste facility.

Adjusted prevalence odds ratios and 95% confidence intervals [CI] are reported in Table 5.4. Adjusting for the effect of population density and region, the odds of any solid waste facility are generally two to three times higher in non-white block groups, compared to white block groups.  To summarize the relationship between race and presence of solid waste facilities, block groups were combined to compare less white block groups [10 to 100% non-white] to white block groups [<10% non-white].  The odds of any solid waste facility are 2.1 [95% CI: 1.6, 2.9] times higher in less white block groups, compared to white block groups. This relationship is similar for MSWLF [adjPOR: 2.3; 95% CI: 1.6, 3.2], CDLF [adjPOR: 2.4; 95% CI: 1.3, 4.5], and TRANSFER [adjPOR: 2.5; 95% CI: 1.3, 4.7].

In general, there are modest increases in the prevalence odds of any solid waste facility among low-wealth block groups compared to high-wealth block groups.  To summarize the results, lower-wealth block groups [median house value $0 to <100,000] were combined and compared to high-wealth block groups [median house value $100,000 to 804,600]. Accounting for population density and region, the odds of any solid waste facility are 1.4 [95% CI: 0.9, 2.1] times higher in lower-wealth block groups, compared to high-wealth block groups. This relationship is similar for MSWLF [adjPOR: 1.5; 95% CI: 0.9, 2.4], TRANSFER [adjPOR: 1.2; 95% CI: 0.7, 2.1] and INDUS [adjPOR: 1.7; 95% CI: 0.8, 4.0].

Table 5.5 provides results of the combined effect of race and wealth on prevalence of any solid waste facility, adjusted for population density and region. The odds of any solid waste facility increase as median house value decreases among white block groups.  Among high-wealth and medium-wealth block groups, the odds of any solid waste facility increase as the percent non-white population increases.

## D. Discussion

This study examined the prevalence of permitted solid waste facilities in North Carolina on December 31, 2003 in relation to block group race and wealth.  The results suggest that accounting for population density and region, the odds of any solid waste facility are greater in non-white block groups compared to white block groups, and low-wealth block groups compared to high-wealth block groups.

This was the first study to examine the statewide prevalence of permitted solid waste facilities in North Carolina, and one of the few studies that examined environmental injustice and solid waste facilities. The results reported here are consistent with another statewide analysis conducted in Massachusetts. Faber and Krieg (9) evaluated the location of solid waste landfills and waste transfer stations in relation to race and income of towns as part of an analysis of cumulative exposures to ecological hazards. They report higher concentrations of these facilities among non-white and lower-income communities compared to white and higher-income communities.

The multivariable analysis used in this study accounted for other factors related to solid waste facility location and block group race and wealth. For example, block group population density is strongly related to solid waste facility prevalence. The relationship between proximity to major roads and solid waste facility prevalence was also examined. Proximity to major roads was measured as the distance, in miles, from the block group centroid to the nearest Interstate or United States [US] highway. Block groups in closer proximity to major roads [<1 mile from US highway and <10 miles from Interstate] had the lowest prevalence of solid waste facilities [56/1743, 3.2%], block groups that were close to at least one major road [<1 mile to US highway or <10 miles from Interstate] had a slightly higher prevalence [106/2357, 4.5%], and block groups that were farthest from major roads [≥1 mile from US highway and ≥10 miles from Interstate] had the highest prevalence [89/1161, 7.7%]. Roads are also related to population density and some researchers have even described the major roads running through the urban core of the Piedmont region as North Carolina's Main Street (10). Accounting for population density and region, the odds of any solid waste facility are lower in block groups farthest from major roads, compared to block groups closest to major roads [adjPOR: 0.7; 95% CI: 0.5, 1.1]. Distance to major roads was not included in final models that describe the relationship between race, wealth, and prevalence of solid waste facilities. Including these variables did not change the interpretation of effect estimates reported in Table 5.4.

It is important to consider some limitations of the study. This study relied on census data and census defined geographic units. Census block groups were used as the unit of analysis since they are the smallest unit for which wealth data were available. Census block groups do not represent meaningful community boundaries.

This study examined select solid waste facility types. Although the facilities included in the study represent the major waste facility types, different patterns may exist for facility types that could not be evaluated in this study. Only waste facilities permitted by the state could be included due to difficulties in identifying all facilities used for waste disposal before regulations were enacted in the early 1980's.

Latitude and longitude coordinates were used to represent facility location and assign the block group level outcome. Using a point to represent solid waste facilities could lead to misclassification of the outcome block group assignment. The method used to obtain and verify coordinates was more sensitive to correctly identifying the block groups that contained the waste disposal area or transfer station building rather than block groups that contained the facility gate entrance, when these block groups are different. A pilot test was conducted for 52 solid waste facilities to compare the coordinates obtained from TerraFly, based on the waste disposal area, to the coordinates available from the NCCGIA, which were reported to be taken at the gate entrance. In this pilot test, block group assignment differed between these methods for only one facility. This represented an extreme example where the facility gate entrance was located in a different county than the waste disposal area.

This study examined the prevalence of solid waste facilities as of December 31, 2003. The cross-sectional design used to evaluate the current distribution of solid waste facilities could not address the race and wealth characteristics at the time the facilities were sited. The race and wealth characteristics at the time of facility permitting are described in Chapter 6.

The current distribution of solid waste facilities in communities is important as proposals to locate additional facilities in the state are considered. Non-white and low-wealth populations in North Carolina have poorer health outcomes than white and wealthier North Carolinians (21). As discussed in Chapter 2, solid waste facilities may impact health through a variety of mechanisms including the built environment. For example, solid waste facilities may detract health promoting facilities [*e.g.* food stores, walking trails] while attracting health limiting facilities [*e.g.* other solid waste facilities or polluting sources]. Malodors from landfills have been reported at middle schools in North Carolina (19). Actual and anticipated malodors from solid waste facilities may limit participation in outdoor physical activity.

In addition to the disproportionate burden of solid waste facilities reported in this study, non-white and low-wealth communities in North Carolina also share a disproportionate burden of pollution from confined swine feeding operations at home (32) and at school (20). This study can be used to inform public policy decisions and public action relating to solid waste management and environmental injustice.

**Table 5.1: Population density by block group race and wealth, North Carolina and regions, 2000[1]**

| | NC | | MOUNTAIN | | PIEDMONT | | COASTAL PLAIN | | TIDEWATER | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **#** | **mean** | **#** | **mean** | **#** | **mean** | **#** | **mean** | **#** | **mean** |
| **All block groups** | 5,261 | 1,187 | 835 | 550 | 2,826 | 1,501 | 1,087 | 935 | 513 | 1,031 |
| **Percent non-white[2]** | | | | | | | | | | |
| 0 to <10 | 1,562 | 673 | 587 | 383 | 769 | 857 | 56 | 1,037 | 150 | 729 |
| 10 to <20 | 985 | 899 | 142 | 740 | 625 | 995 | 131 | 742 | 87 | 707 |
| 20 to <30 | 647 | 1,102 | 49 | 1,068 | 372 | 1,386 | 150 | 687 | 76 | 559 |
| 30 to <50 | 878 | 1,288 | 37 | 1,453 | 437 | 1,705 | 286 | 707 | 118 | 1,101 |
| 50 to 100 | 1,189 | 2,072 | 20 | 1,156 | 623 | 2,727 | 464 | 1,198 | 82 | 2,267 |
| **Median house value[3]** | | | | | | | | | | |
| 0 to < 60,000 | 822 | 1,378 | 78 | 1,006 | 295 | 2,134 | 373 | 843 | 76 | 1,447 |
| 60,000 to < 75,000 | 1,105 | 1,084 | 175 | 492 | 465 | 1,608 | 349 | 739 | 116 | 918 |
| 75,000 to <100,000 | 1,689 | 1,026 | 366 | 488 | 904 | 1,229 | 252 | 1,154 | 167 | 918 |
| 100,000 to 804,600 | 1,645 | 1,326 | 216 | 537 | 1,162 | 1,508 | 113 | 1,354 | 154 | 1,034 |

1. Population density is defined as persons per square mile; 2. Percent non-white is defined as percent of the block group population who are not white, non-Hispanic alone; 3. Median house value is defined as the median house value [in US dollars] for all owner-occupied housing units.

**Table 5.2: Number and types of solid waste facilities, North Carolina; by select characteristics**

| | ALL | MSWLF[1] | CDLF | TRANS | INDUS | TIRELF |
|---|---|---|---|---|---|---|
| **Number of facilities** | 419 | 201 | 75 | 92 | 48 | 3 |
| **% total[2]** | 100.0 | 48.0 | 17.9 | 22.0 | 11.5 | 0.7 |
| **% open[3]** | 46.3 | 19.9 | 84.0 | 85.9 | 20.8 | 66.7 |
| **% lined[4]** | 11.7 | 21.4 | 0.0 | 0.0 | 12.5 | 0.0 |
| **% issued permit[5]** | | | | | | |
| <1970 | 3.8 | 6.0 | 0.0 | 0.0 | 8.3 | 0.0 |
| 1970-1979 | 27.7 | 49.8 | 0.0 | 0.0 | 33.3 | 0.0 |
| 1980-1989 | 14.6 | 18.9 | 1.3 | 3.3 | 35.4 | 66.7 |
| 1990-1999 | 40.6 | 18.9 | 78.7 | 75.0 | 6.3 | 33.3 |
| 2000-2003 | 8.8 | 0.5 | 18.7 | 20.7 | 6.3 | 0.0 |
| missing | 4.5 | 6.0 | 1.3 | 1.0 | 10.4 | 0.0 |
| **% own/operated[6]** | | | | | | |
| public | 68.0 | 90.0 | 77.3 | 48.9 | 2.1 | 0.0 |
| private | 26.7 | 8.0 | 21.3 | 32.6 | 97.9 | 100.0 |
| public/private | 5.0 | 2.0 | 1.3 | 17.4 | 0.0 | 0.0 |
| missing | 0.2 | 0.0 | 0.0 | 1.1 | 0.0 | 0.0 |

1. MSWLF: municipal solid waste landfill, CDLF: construction and demolition debris landfill, TRANS: waste transfer station, INDUS: industrial solid waste landfill, TIRELF: tire landfill; 2. Percent based on total facilities included in study. Other percentages in table refer to the column percent; 3. Accepting waste for disposal/ transfer on Dec 31, 2003; 4. Facility is equipped with a liner system; 5. Permit to construct, permit to operate or letter of approval; 6. Private includes owned/operated by military, private waste management companies, or special uses [e.g., university, resort, private industrial firms]

**Table 5.3: Prevalence and crude prevalence odds ratios of solid waste facilities and race and wealth, by facility type: North Carolina block groups[1]**

| | | Any SWF [2] | | | Any MSWLF | | | Any CDLF | | | Any TRANSFER | | | Any INDUS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **N** | **%[3]** | **POR[4]** | **[95%CI]** | **%** | **POR** | **[95%CI]** | **%** | **POR** | **[95%CI]** | **%** | **POR** | **[95%CI]** | **%** | **POR** | **[95%CI]** |
| **Total [5]** | 5,261 | 4.8 | | | 3.2 | | | 1.4 | | | 1.6 | | | 0.8 | | |
| **Percent non- white[6]** | | | | | | | | | | | | | | | | |
| 0 to <10 | 1,562 | 4.3 | 1.0[7] | | 2.9 | 1.0[7] | | 1.1 | 1.0[7] | | 1.1 | 1.0[7] | | 0.9 | 1.0[7] | |
| 10 to <20 | 985 | 5.6 | 1.4 | [1.0, 1.9] | 3.7 | 1.3 | [0.9, 1.8] | 1.4 | 1.3 | [0.7, 2.6] | 1.4 | 1.3 | [0.7, 2.5] | 1.0 | 1.2 | [0.5, 2.5] |
| 20 to <30 | 647 | 6.5 | 1.6 | [1.0, 2.4] | 4.6 | 1.6 | [1.1, 2.5] | 2.3 | 2.2 | [1.1, 4.6] | 2.6 | 2.3 | [1.2, 4.6] | 0.8 | 0.9 | [0.3, 2.5] |
| 30 to <50 | 878 | 4.9 | 1.2 | [0.9, 1.7] | 3.0 | 1.0 | [0.7, 1.5] | 1.6 | 1.5 | [0.7, 3.1] | 2.1 | 1.8 | [1.0, 3.3] | 0.7 | 0.8 | [0.3, 2.1] |
| 50 to 100 | 1,189 | 3.7 | 1.0 | [0.7, 1.3] | 2.4 | 0.9 | [0.6, 1.3] | 1.0 | 0.9 | [0.4, 1.9] | 1.5 | 1.5 | [0.9, 2.4] | 0.5 | 0.6 | [0.2, 1.5] |
| *10 to 100[8]* | *3,699* | *5.0* | *1.3* | *[1.0, 1.6]* | *3.3* | *1.2* | *[0.9, 1.6]* | *1.5* | *1.4* | *[0.8, 2.3]* | *1.8* | *1.7* | *[1.0, 2.7]* | *0.7* | *0.9* | *[0.4, 1.7]* |
| **Median house value[9]** | | | | | | | | | | | | | | | | |
| 100 to 804.6 | 1,645 | 3.5 | 1.0[7] | | 1.8 | 1.0[7] | | 1.2 | 1.0[7] | | 1.3 | 1.0[7] | | 0.4 | 1.0[7] | |
| 75 to <100 | 1,689 | 5.0 | 1.4 | [1.1, 1.9] | 3.8 | 2.1 | [1.4, 3.2] | 1.6 | 1.4 | [0.7, 2.7] | 1.7 | 1.3 | [0.7, 2.2] | 0.8 | 1.8 | [0.9, 3.9] |
| 60 to < 75 | 1,105 | 6.3 | 1.8 | [1.3, 2.4] | 4.3 | 2.4 | [1.6, 3.7] | 1.4 | 1.2 | [0.6, 2.5] | 2.4 | 1.7 | [1.0, 3.0] | 1.3 | 3.0 | [1.6, 5.9] |
| 0 to < 60 | 822 | 4.7 | 1.3 | [0.9, 1.9] | 3.2 | 1.8 | [1.1, 2.9] | 1.3 | 1.2 | [0.6, 2.5] | 1.1 | 0.8 | [0.4, 1.6] | 0.9 | 2.0 | [0.7, 5.5] |
| *0 to < 100[10]* | *3,616* | *5.4* | *1.5* | *[1.2, 2.0]* | *3.8* | *2.1* | *[1.5, 3.1]* | *1.5* | *1.3* | *[0.7, 2.3]* | *1.7* | *1.3* | *[0.8, 2.1]* | *0.9* | *2.2* | *[1.2, 4.2]* |

1. Prevalence defined as the presence of any solid waste facility issued permit on or before December 31, 2003; 2. SWF: Solid waste facility, MSWLF: municipal solid waste landfill, CDLF: construction and demolition debris landfill, TRANSFER: waste transfer station, INDUS: industrial solid waste landfill; 3. Percent of block groups with any solid waste facility; 4. Prevalence odds ratios [POR] and 95% confidence intervals [CI] computed using GEE with exchangeable correlation matrix; 5. Total refers to all block groups; 6. Percent non-white of block group population, Census 2000; 7. Referent group; 8. Results obtained from separate model to summarize less white block groups compared to white block groups; 9. Median house value in US dollars for all owner-occupied housing units [in thousands], Census 2000; 10. Results obtained from separate model to summarize less wealthy block groups compared to high-wealth block groups.

**Table 5.4: Adjusted prevalence odds ratios and 95% confidence intervals of solid waste facilities and race and wealth: North Carolina block groups [1]**

| | | Any SWF [2] | | Any MSWLF | | Any CDLF | | Any TRANSFER | | Any INDUS | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **N** | **adj POR[3]** | **[95% CI]** | **adj POR** | **[95% CI]** | **adj POR** | **[95% CI]** | **adj POR** | **[95% CI]** | **adj POR** | **[95% CI]** |
| **Percent non- white [4]** | | | | | | | | | | | |
| 0 to <10 | 1,562 | 1.0[5] | | 1.0[5] | | 1.0[5] | | 1.0[5] | | 1.0[5] | |
| 10 to <20 | 985 | 1.8 | [1.3, 2.6] | 1.9 | [1.3, 2.8] | 1.7 | [0.9, 3.4] | 1.6 | [0.7, 3.6] | 1.7 | [0.7, 3.9] |
| 20 to <30 | 647 | 2.5 | [1.6, 4.0] | 2.9 | [1.8, 4.8] | 3.5 | [1.6, 7.6] | 3.3 | [1.5, 7.5] | 1.5 | [0.5, 4.9] |
| 30 to <50 | 878 | 2.2 | [1.4, 3.3] | 2.1 | [1.3, 3.6] | 2.9 | [1.3, 6.4] | 2.9 | [1.4, 6.1] | 1.6 | [0.5, 4.8] |
| 50 to 100 | 1,189 | 2.8 | [1.9, 4.1] | 2.9 | [1.8, 4.8] | 2.7 | [1.1, 6.4] | 3.5 | [1.7, 7.3] | 1.8 | [0.5, 6.0] |
| *10 to 100[6]* | *3,699* | *2.1* | *[1.6, 2.9]* | *2.3* | *[1.6, 3.2]* | *2.4* | *[1.3, 4.5]* | *2.5* | *[1.3, 4.7]* | *1.6* | *[0.7, 3.6]* |
| **Median house value[7]** | | | | | | | | | | | |
| 100,000 to 804,600 | 1,645 | 1.0[5] | | 1.0[5] | | 1.0[5] | | 1.0[5] | | 1.0[5] | |
| 75,000 to <100,000 | 1,689 | 1.2 | [0.8, 1.9] | 1.4 | [0.9, 2.3] | 0.9 | [0.4, 1.9] | 1.1 | [0.6, 2.1] | 1.3 | [0.5, 3.4] |
| 60,000 to < 75,000 | 1,105 | 1.8 | [1.1, 2.8] | 1.7 | [1.0, 2.9] | 0.8 | [0.3, 1.8] | 1.5 | [0.8, 3.0] | 2.5 | [1.1, 5.6] |
| 0 to < 60,000 | 822 | 1.5 | [0.9, 2.5] | 1.5 | [0.8, 2.7] | 0.8 | [0.3, 2.1] | 0.8 | [0.3, 1.8] | 2.0 | [0.6, 6.7] |
| *0 to <100,000[8]* | *3,616* | *1.4* | *[0.9, 2.1]* | *1.5* | *[0.9, 2.4]* | *0.9* | *[0.4, 1.8]* | *1.2* | *[0.7, 2.1]* | *1.7* | *[0.8, 4.0]* |

1. Prevalence defined as the presence of any solid waste facility issued permit on or before December 31, 2003; 2. SWF: Solid waste facility, MSWLF: municipal solid waste landfill, CDLF: construction and demolition debris landfill, TRANSFER: waste transfer station, INDUS: industrial solid waste landfill; 3. Prevalence odds ratios and 95% confidence intervals [CI] computed using GEE with exchangeable correlation matrix, adjusted for population density and region; 4. Percent non-white of block group population, Census 2000; 5. Referent group; 6. Results obtained from separate model to summarize less white block groups compared to white block groups; 7. Median house value for all owner-occupied housing units, Census 2000; 8. Results obtained from separate model to summarize less wealthy block groups compared to high-wealth block groups.

**Table 5.5: Prevalence, adjusted prevalence odds ratios and 95% confidence intervals of the presence of any solid waste facility, by race and wealth: North Carolina block groups [1]**

| | 0 to <10% non-white[2] | | | | 10 to <30% non-white | | | | 30 to 100% non-white | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Median house value[3]** | **#[4]** | **%[5]** | **adj POR[6]** | **[95% CI]** | **#** | **%** | **adj POR** | **[95% CI]** | **#** | **%** | **adj POR** | **[95% CI]** |
| **$100,000 to 804,600** | 725 | 2.1 | 1.0[7] | | 642 | 5.0 | 3.8 | [1.7, 8.3] | 278 | 3.6 | 5.6 | [2.5, 12.5] |
| **$60,000 to <100,000** | 775 | 6.1 | 2.1 | [1.2, 3.8] | 850 | 6.5 | 3.1 | [1.7, 5.8] | 1,169 | 4.5 | 4.1 | [2.3, 7.3] |
| **$ 0 to < 60,000** | 62 | 8.1 | 3.1 | [1.0, 9.6] | 140 | 7.1 | 4.1 | [1.9, 8.9] | 620 | 3.9 | 3.0 | [1.6, 5.7] |

1. Prevalence defined as the presence of any solid waste facility issued permit on or before December 31, 2003; 2. Percent non-white of block group population, Census 2000; 3. Median house value for all owner-occupied housing units, Census 2000; 4. Number of block groups in category; 5. Percent of block groups with any solid waste facility; 6. Prevalence odds ratios [POR] and 95% confidence intervals [CI] computed using GEE with exchangeable working correlation matrix, adjusted for population density and region; 7. Referent group.

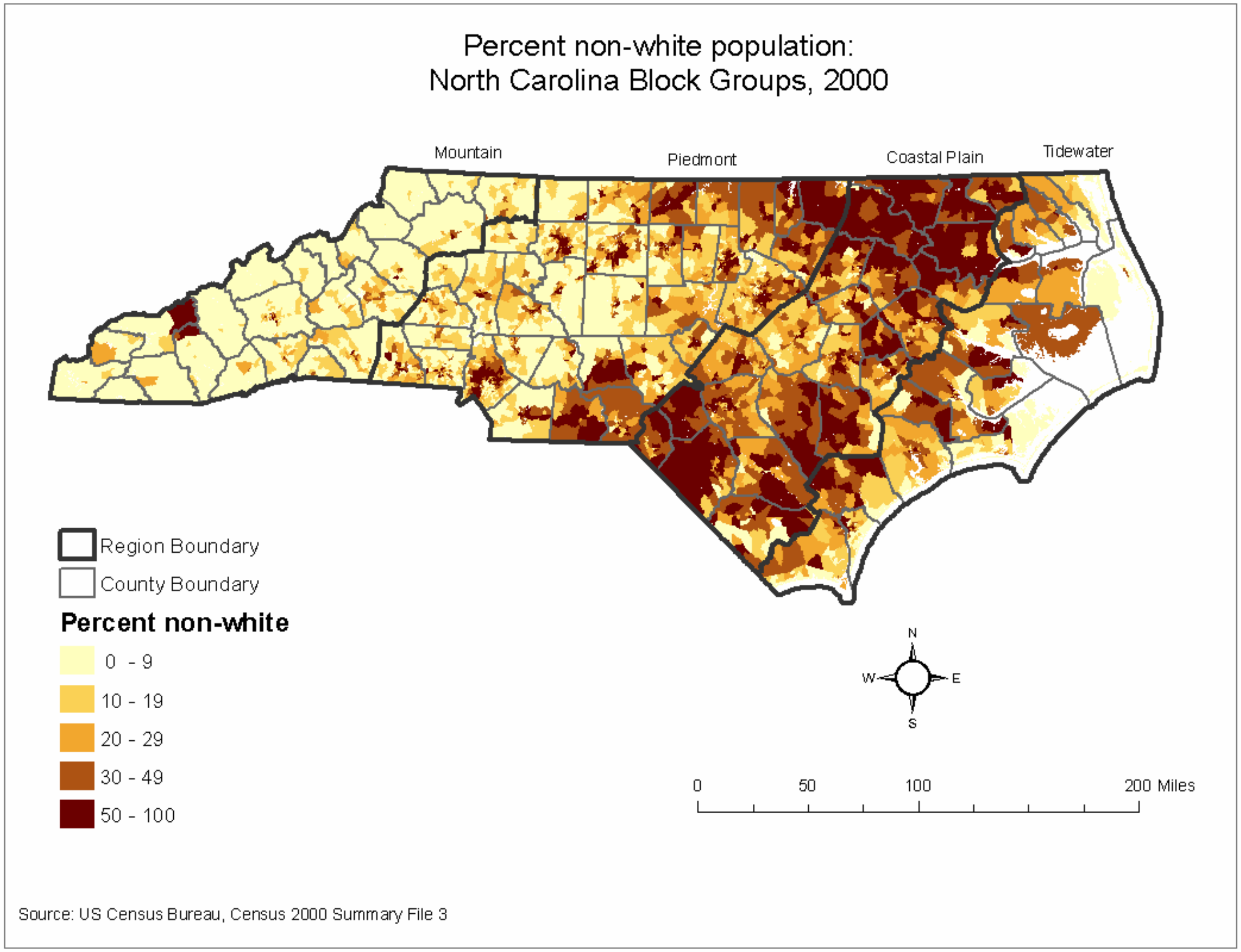



**Figure 5.1: Percent non-white population, North Carolina block groups, 2000**

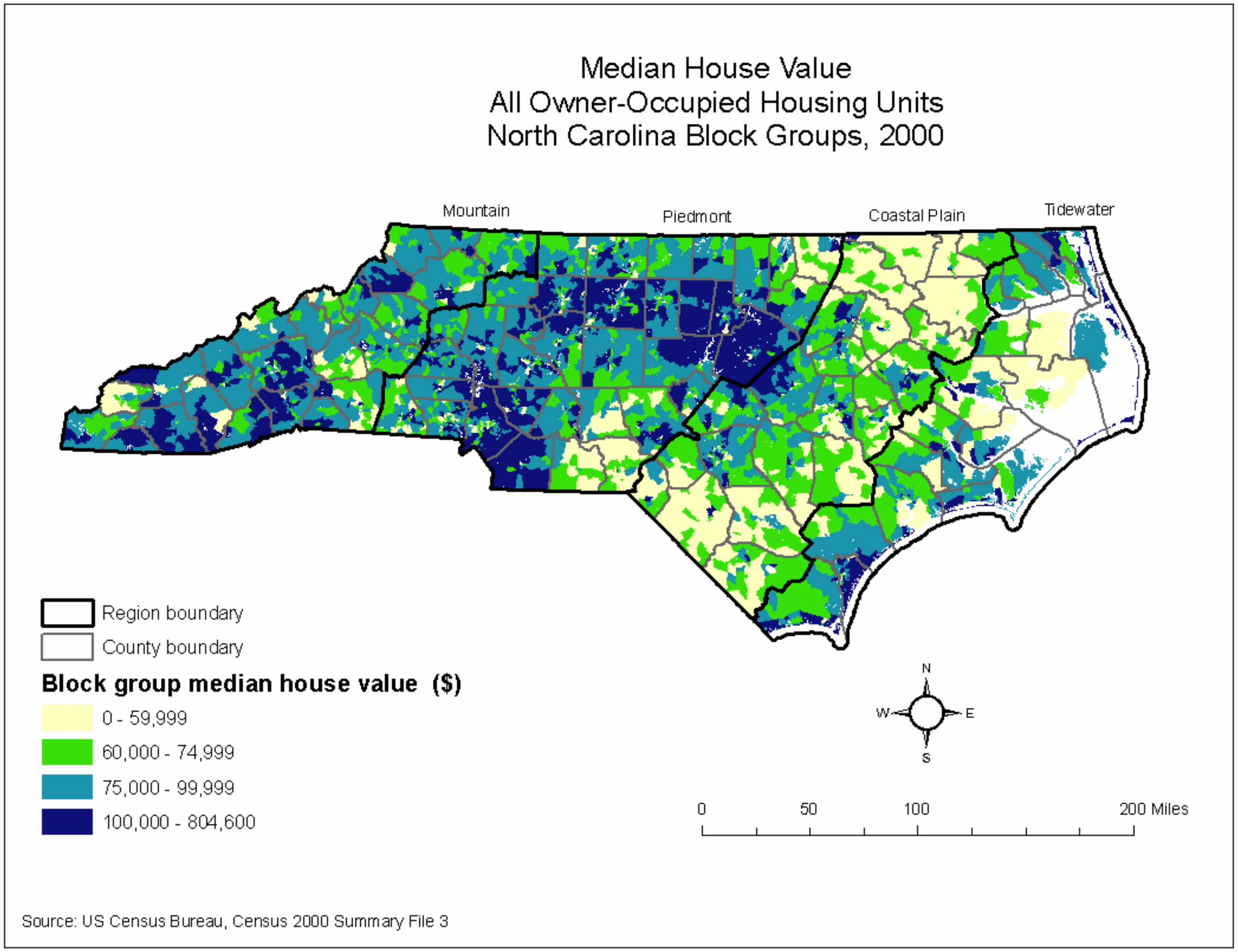
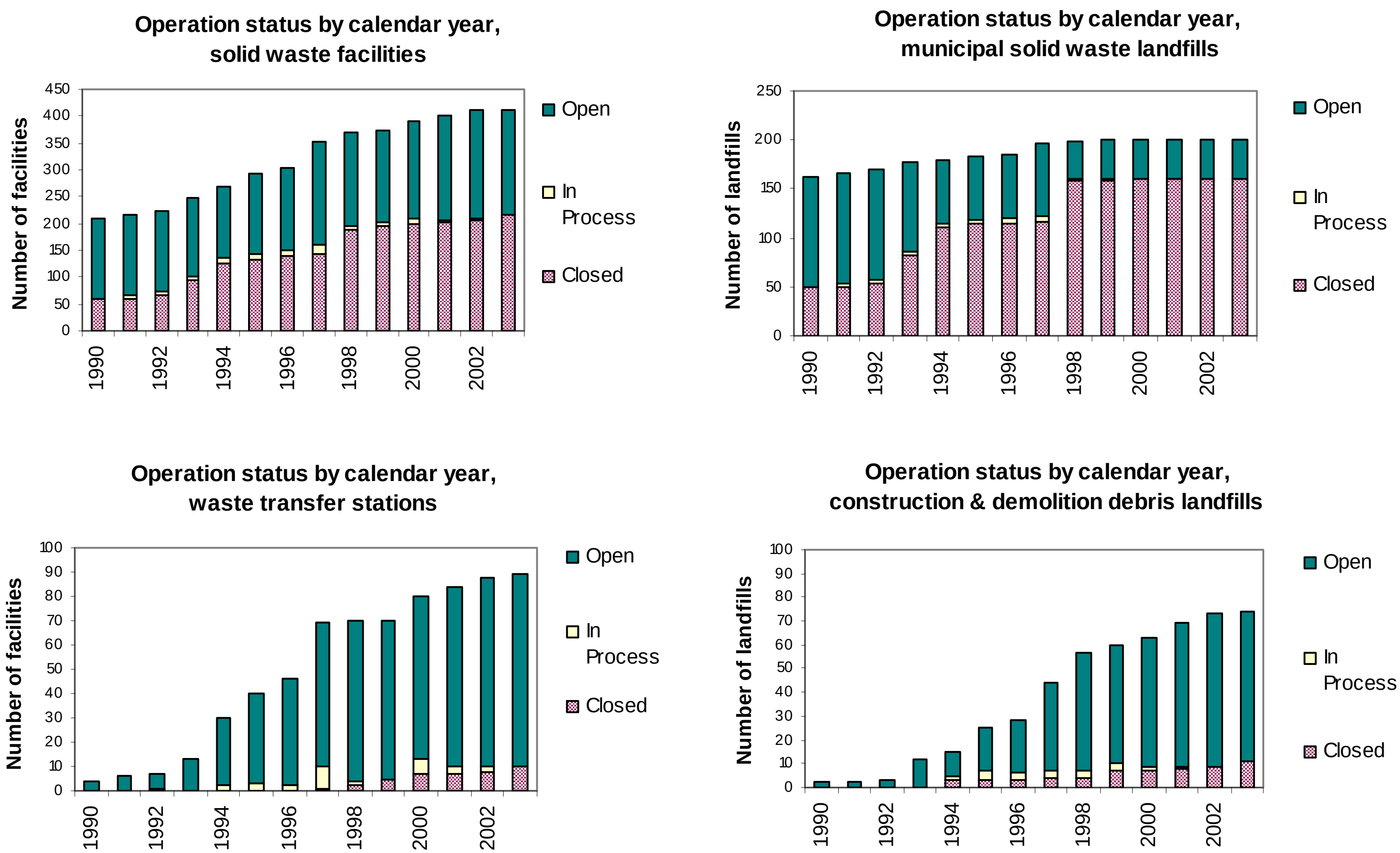



**Figure 5.2: Median house value, all owner-occupied housing units, North Carolina block groups, 2000**




Open: actively accepting waste for disposal/transfer; In Process: facility issued permit to construct but not yet received permit to operate; Closed: facility is no longer actively accepting waste for disposal/transfer

**Figure 5.3: Operation status by calendar year: priority solid waste facilities, municipal solid waste landfills, waste transfer stations, and construction & demolition debris landfills**

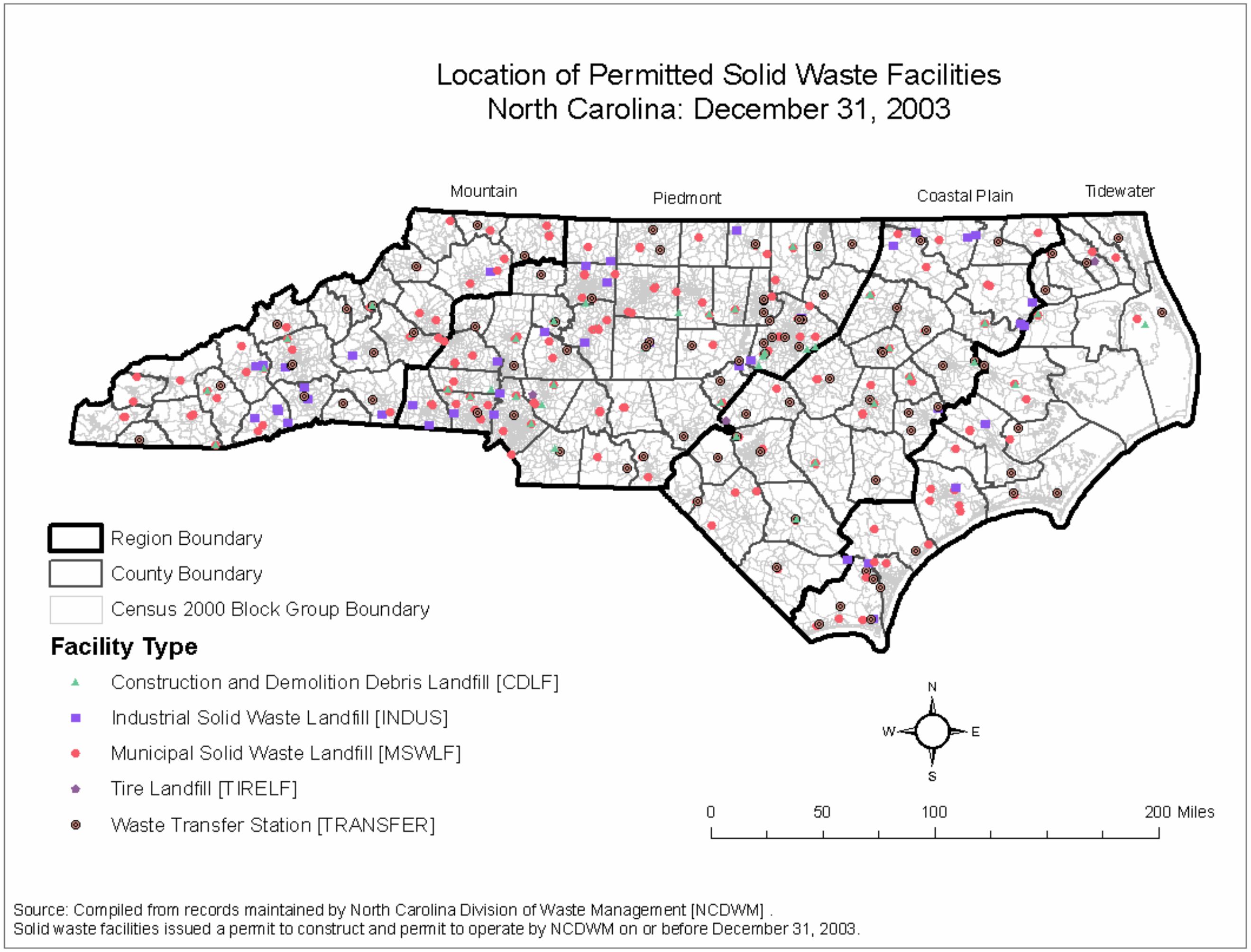



**Figure 5.4: Location of permitted solid waste facilities, North Carolina: December 31, 2003**

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# CHAPTER 6

# RESULTS AIM 2:

# RACE, WEALTH AND OCCURRENCE OF SOLID WASTE FACILITIES IN NORTH CAROLINA, 1990-2003

## A. Introduction

In 2003, Americans produced 236 million tons of municipal solid waste, the majority of which was disposed in landfills (21). Proper solid waste management has long been a public health concern. Improvements in organized solid waste collection and disposal are among the factors that contributed to the control of infectious diseases, which is considered one of ten major achievements in US public health in the 20th century, according to the US Centers for Disease Control and Prevention [CDC] (3). Yet, waste management practices continue to present health and environmental concerns. These concerns include direct effects of potential exposures to groundwater contamination (13), odorous and non-odorous air emissions (1), and traffic safety issues related to transportation of wastes (4). Solid waste facilities can affect quality of life and well-being and may limit opportunities for physical activity.

Previous research indicates that the prevalence of solid waste facilities in North Carolina is greater in non-white block groups compared to white block groups and low-wealth block groups compared to high-wealth block groups [see Chapter 5]. These results are consistent with other environmental justice studies that have found higher concentrations of solid waste facilities in non-white and low-income towns compared to white and high-income towns in Massachusetts (5), and studies in North Carolina which found non-white and low-wealth communities share a disproportionate burden of pollution from confined swine feeding operations (11, 22). The use of cross-sectional designs to evaluate environmental injustice concerns has been criticized for failing to address explanations for this observed pattern (2). One possible explanation for that pattern is that non-white and low-wealth communities are more likely to be selected for environmental hazards. Another explanation is that non-white and low-wealth populations move into an area [or white and wealthy populations move out] after the facility is sited (14, 15).

The potential for disproportionate siting of solid waste facilities has important implications for public health. As discussed in Chapter 2, solid waste facilities impact the built environment. For example, siting of solid waste facilities may result in attracting additional solid waste facilities or other polluting sources to an area which in turn may limit the opportunities for health promoting resources. Additionally, the malodors, traffic, and litter associated with solid waste facility operations can impede the use of walking trails or sidewalks that promote increased physical activity which is important for cardiovascular health and reducing obesity (8). Non-white and low-wealth populations have higher rates of cardiovascular illness and diabetes (12), and therefore may be more susceptible to the impacts of solid waste facilities (9).

This study was conducted to evaluate the occurrence of solid waste facilities in non-white communities compared to white communities, and low-wealth communities compared to high-wealth communities.

## B. Materials and methods

Solid waste facility data used in this analysis were obtained from facility records maintained by the North Carolina Division of Waste Management [NCDWM]. For the purpose of this study, solid waste facilities were defined as municipal solid waste landfills [MSWLF], construction and demolition debris landfills [CDLF], industrial solid waste landfills [INDUS], tire landfills [TIRELF] and waste transfer stations [TRANSFER]. To be included in this analysis, solid waste facilities must have been issued a permit to construct and/or permit to operate between January 1, 1990 and December 31, 2003.

Communities in North Carolina are the conceptual basis for the study population. Populated census block groups in 1990 and 2000 were used as the unit of analysis to define communities [n=5,257]. Because block group boundaries change over time, a standard geographic area was used to compute changes over time so that changes in the population are not a reflection of changing geographic boundaries. This analysis used data from GeoLytics which estimates the 1990 census data in 2000 block group boundaries (7) and from the US Census Bureau decennial Census 2000 (18). For intercensal years, linear interpolation was used to estimate the population and wealth characteristics of block groups for 1991-1999. Population and wealth characteristics for 2001-2003 used values from the year 2000. For this analysis, median house values for specified owner-occupied housing units were used as an indicator of community wealth. Median house values in 1990 were adjusted for inflation to year 2000 US dollars (19) prior to interpolation.

The occurrence of solid waste facilities was defined as the first issuance of a solid waste facility permit in a block group between January 1, 1990 and December 31, 2003. Solid waste facility permit dates were based on the date the permit to construct was issued. For facilities not requiring a permit to construct, the permit to operate date was used. If the exact permit date was not known, the dates were estimated using the midpoint of the known month and year, or the midpoint of the year.

Of the block groups that received at least one permitted solid waste facility between 1990-2003, the majority [93/146] also contained at least one solid waste facility permitted before January 1, 1990. To account for the difference in the baseline risk of new solid waste facility permits, a stratified analysis was conducted based on the presence of any previous solid waste facility in the block group. The first group consisted of block groups that did not have a permitted solid waste facility on January 1, 1990. In this group, all block groups enter the risk set on the same day [January 1, 1990] and exit when the first solid waste facility permit is issued [event] or the end of follow-up [censored]. The second group began with those block groups that had a permitted solid waste facility on January 1, 1990. On the day that a solid waste facility is issued in the solid waste facility free group, the block group then enters this group and is followed until a permit is issued [event] or until the end of follow-up [censored].

The main research questions evaluated the occurrence of new permitted solid waste facilities by race and wealth of block groups over time. Block group percent non-white, median house value, and population density were considered time-varying covariates. The values were set to change on April 1 of each year, to be consistent with the day of the US Census enumeration. Time fixed covariates were also evaluated as potential confounders. These include region, distance to urban area, and distance to nearest road.

The relationship between where waste is produced and where waste is disposed is an important relationship that has not been evaluated. Due to the lack of specific information on waste production, a summary measure was created as an indicator of waste production at the county level. This measure is the average tons per person of municipal solid waste and construction and demolition debris waste that is disposed by county of origin, over fiscal years 1991-2004. Block groups are classified based on location within counties that on average have relatively low, medium, or high waste disposal per person. For this specific analysis, the outcome was defined based on the facility type [MSWLF or CDLF] of the first permit issued in a block group between 1990-2003.

Extended Cox proportional hazards regression was used to obtain hazard ratios using the SAS PHREG procedure (17). Due to the nesting of block groups within counties, the robust sandwich estimate option was used to compute standard errors.

## C. Results

Figure 6.1 illustrates the location of solid waste facilities permitted in North Carolina between 1990-2003. Table 6.1 describes the 207 solid waste facilities issued a permit to construct and/or permit to operate between January 1, 1990 and December 31, 2003 included in this study. Waste transfer stations comprise the largest category of solid waste facilities issued permits during this time period [42%] followed by construction and demolition debris landfills [35%]. The majority of facilities issued a permit during this time period were actively receiving waste for disposal or transfer on December 31, 2003. All of the municipal solid waste landfills issued a permit during this time period were lined, reflecting the federal law that required MSWLF newly constructed after October 1993 to meet minimum engineering control standards (20). MSWLF that did not meet this new requirement were required to cease accepting municipal solid waste for disposal on or before December 31, 1997. While these facilities closed, other facilities opened in their place. Sixty-four percent [64%] of MSWLF, 71% of CDLF, and 49% of TRANSFER stations issued a permit between 1990 and 2003 were located at a site that contained an unlined MSWLF.

At the time the first permit was issued, the majority [65%] of solid waste facilities were permitted to accept waste generated within the county that the facility was located. Few facilities [2%] were permitted to receive out-of state waste. At the time of the most recent permit issued to facilities, the percent receiving only wastes generated within the county had decreased while the percent receiving wastes from outside of the county had increased.

The majority of solid waste facilities permitted during this time were publicly owned and operated [64%]. However, a trend towards vertical integration of the solid waste industry can be seen among the solid waste facilities issued permits in North Carolina between 1990-2003. Of the 207 solid waste facilities issued a permit during this time period, 22% were owned and operated by private waste management companies, compared to 2% of the 212 solid waste facilities issued a permit before 1990.

Table 6.2 describes the associations between the first permitted solid waste facility and race and wealth, by presence of any previous solid waste facility. On average, non-white block groups had a higher rate of permitted solid waste facilities than white block groups. Among block groups that were solid waste facility free in 1990, less-white block groups [10 to 100% non-white] received new permitted solid waste facilities at about twice the rate [HR=2.2; 95% CI: 1.2, 3.8] of white block groups, accounting for block group population density. Among block groups that had a previous solid waste facility, a modest increase in the rate of new solid waste facility permits was observed in less-white block groups [20 to 100% non-white] compared to more-white block groups [0 to 20% non-white], accounting for block group population density, region, and distance to urban area [HR=1.2; 95% CI: 0.8, 2.0].

Among solid waste facility free block groups, lower wealth block groups [<$100,000] had a lower rate [HR=0.6; 95%CI: 0.3, 1.1] of permitted solid waste facilities compared to high-wealth block groups [$100,000 to 787,100], accounting for block group population density. Among block groups with a previous solid waste facility, low-wealth block groups had a higher rate of permitted solid waste facilities compared to high-wealth block groups [HR=1.3; 95% CI: 0.8, 2.2], accounting for block group population density, region, and distance to urban area. It should be noted that although the range of median house values in the highest wealth group is $100,000 to $787,100, there were no solid waste facilities permitted in block groups that had median house values greater than $200,000 at the time the facility was permitted.

Table 6.3 provides the associations between first permitted solid waste facility and the combined effect of race and wealth, by presence of any previous solid waste facility. Among block groups that were solid waste facility free in 1990, low-wealth and white block groups had a lower rate of permitted solid waste facilities compared to high-wealth and white block groups [HR=0.4; 95% CI: 0.2, 1.3], while low-wealth and less white block groups had a higher rate compared to high-wealth and white block groups [HR=1.2; 95% CI: 0.6, 2.5], accounting for block group population density. However, these estimates are imprecise.

During 1990-2003, there was a growing trend towards vertical integration of the solid waste industry. Table 6.4 provides the associations between the first permitted solid waste facility and race and wealth, by the owner/operator of the first solid waste facility. On average, the rate of privately owned and / or operated solid waste facilities was 2.4 [95% CI: 1.0, 5.8] times higher in block groups with 10 to 100% non-white population, compared to block groups with less than 10% non-white population, adjusting for the presence of a solid waste facility at baseline, block group population density, distance to nearest urban area, distance to nearest major road, and region. In contrast, after adjustment for the same factors, the rate of publicly owned and operated solid waste facilities was about the same in block groups with 10 to 100% non-white population, compared to block groups with less than 10% non-white population [HR=1.0; 95% CI: 0.6, 1.8].

Table 6.5 describes the associations between first permitted solid waste facility classified as MSWLF or CDLF and per capita waste disposal. Accounting for presence of a solid waste facility at baseline and block group population density, block groups in high waste disposal counties received permitted solid waste facilities classified as MSWLF or CDLF at a higher rate than block groups in medium waste disposal counties [HR=1.2; 95% CI: 0.6, 2.1].

## D. Discussion

The results of this analysis suggest that the rate of permitted solid waste facilities was greater in non-white block groups compared to white block groups in North Carolina between 1990-2003. The analysis considered the percent non-white and median house value at the time the solid waste facility permit was issued.  Comparing these results with results of a previous analysis which examined the prevalence of solid waste facilities in 2003, there is evidence to suggest that on average in North Carolina, non-white block groups host a greater burden of solid waste facilities compared to white block groups, and that this relationship is partly due to the rate at which non-white block groups received permitted solid waste facilities compared to white block groups.

On average, increases in the percent non-white population before and after solid waste facilities were permitted were comparable to or less than increases occurring in block groups that did not receive a solid waste facility, and therefore it is not likely that the ‘minority move-in’ [or majority move-out] explain the observed relationship between race and location of solid waste facilities in North Carolina over this time period [data not shown].

On average, among block groups with a previous solid waste facility, the rate of permitted solid waste facilities was higher in lower-wealth block groups compared to high-wealth block groups. However, the reverse relationship was observed among block groups that were solid waste facility free. Using a high-wealth category of greater than $100,000 was necessary due to small numbers, but it does mask the relationship between solid waste facilities among the highest median house values [$200,000 to $787,100], where no block group received a permitted solid waste facility between 1990-2003.

It is possible that median house value for specified owner-occupied housing units measured at the block group level may not capture the relationship between wealth and solid waste facility location. For example, mobile homes and renter-occupied housing units are not included in the computation for the median house value used in this analysis. If a block group contains many mobile homes and renter-occupied units that have lower house values than the non-mobile home owner-occupied housing units, this could result in over-estimation of block group median house value.  Sixteen percent [16.4%] of housing units in North Carolina are classified as mobile homes (18).

This analysis used the solid waste facility permit date rather than the date the solid waste facility siting decision was made. In North Carolina, solid waste facility siting decisions are made at the local government level [*i.e.,* county or municipality]. It was not feasible to obtain information regarding the dates the siting decisions were made. Nor was it possible to obtain information regarding all possible factors that could influence local government decisions, including opportunities for community participation in these decisions.

Solid waste facility siting decisions are often framed as a local issue, and the relationship to solid waste production is typically ignored. Recent news accounts discuss proposals for large landfills in eastern North Carolina that have been promoted to improve economic development (16). This region is less wealthy and contains a larger proportion of non-white residents than other regions in the state. In light of these proposals, state legislators are calling for a moratorium on new solid waste facility permits until the issue can be further evaluated (10).  As this issue is debated in the public policy forum, short term and long term solutions should be considered.  The results of this research suggest that non-white and low-wealth communities are disproportionately burdened with solid waste facilities, and therefore steps should be taken to minimize this burden.  Longer-term solutions are also needed to minimize waste production nationally. While it is important to address solid waste facilities as an important stressor on community health, long term solutions are needed to improve social and economic conditions for all communities (6).

**Table 6.1: Number and types of solid waste facilities issued permit January 1, 1990- December 31, 2003, North Carolina; by select characteristics**

| | ALL | MSWLF[1] | CDLF | TRANS | INDUS | TIRELF |
|---|---|---|---|---|---|---|
| **Number of facilities** | 207 | 39 | 73 | 88 | 6 | 1 |
| **% total[2]** | 100.0 | 18.8 | 35.3 | 42.5 | 2.9 | 0.5 |
| **% open[3]** | 88.4 | 92.3 | 84.9 | 88.6 | 100.0 | 100.0 |
| **% lined[4]** | 21.7 | 100.0 | 0.0 | 0.0 | 100.0 | 0.0 |
| **% issued permit[5]** | | | | | | |
| 1990-1992 | 8.2 | 20.5 | 1.4 | 5.7 | 33.3 | 100.0 |
| 1993-1996 | 40.1 | 41.0 | 35.6 | 45.5 | 16.7 | 0.0 |
| 1997-1999 | 33.8 | 35.9 | 43.8 | 27.3 | 0.0 | 0.0 |
| 2000-2003 | 17.9 | 2.6 | 19.2 | 21.6 | 50.0 | 0.0 |
| **% own/operated[6]** | | | | | | |
| public | 63.8 | 76.9 | 78.1 | 50.0 | 16.7 | 0.0 |
| private | 27.5 | 18.0 | 20.6 | 33.0 | 83.3 | 100.0 |
| public/private | 8.7 | 5.1 | 1.4 | 17.0 | 0.0 | 0.0 |
| **% waste source at time of first permit[7]** | | | | | | |
| county | 64.7 | 59.0 | 76.7 | 62.5 | 0.0 | 0.0 |
| region/NC | 27.1 | 30.8 | 20.6 | 31.8 | 0.0 | 100.0 |
| out of state | 2.4 | 7.7 | 1.4 | 1.1 | 0.0 | 0.0 |
| other | 5.8 | 2.6 | 1.4 | 4.6 | 100.0 | 0.0 |
| **% waste source most recent[8]** | | | | | | |
| county | 57.5 | 48.7 | 67.1 | 58.0 | 0.0 | 0.0 |
| region/NC | 33.8 | 35.9 | 30.1 | 37.5 | 0.0 | 100.0 |
| out of state | 2.9 | 12.8 | 1.4 | 0.0 | 0.0 | 0.0 |
| other | 5.8 | 2.6 | 1.4 | 4.6 | 100.0 | 0.0 |
| **% at unlined MSWLF[9]** | 58.5 | 64.1 | 71.2 | 48.9 | 16.7 | 0.0 |

1. MSWLF Municipal Solid Waste Landfill, CDLF Construction & Demolition debris Landfill, TRANS Waste Transfer Station, INDUS Industrial Solid Waste Landfill, TIRELF Tire Landfill; 2. Percent based on total facilities issued permit to construct and/or permit to operate between 1990-2003. Other percentages in table refer to the column percent; 3. Accepting waste for disposal/ transfer on Dec 31, 2003; 4. Facility is equipped with a liner system that adheres to Subtitle D specifications; 5. Permit date refers to the first permit to construct or permit to operate issued to facility; 6. Private includes owned/operated by military, private waste management companies, or private industrial firms; 7. Source of waste when facility was issued the first permit to construct or permit to operate issued to facility; 8. Source of waste at most recent permit; 9. Located at site that contains an unlined MSWLF.

**Table 6.2: Associations between first permitted solid waste facility and race and wealth, by presence of any previous solid waste facility: North Carolina block groups, 1990-2003**

**Solid Waste Facility Free [n=5,059]**

| | | | Crude | | Adjusted[1] | |
|---|---|---|---|---|---|---|
| | #[2] | YEARS[3] | HR[4] | [95% CI][5] | HR | [95% CI] |
| **Percent non- white** | | | | | | |
| 0 to <10 | 13 | 23,983 | 1.0[6] | | 1.0[6] | |
| 10 to <20 | 10 | 12,846 | 1.4 | [0.7, 3.2] | 1.6 | [0.7, 3.6] |
| 20 to <30 | 11 | 8,346 | 2.4 | [1.2, 4.9] | 3.0 | [1.5, 6.1] |
| 30 to <50 | 8 | 11,111 | 1.3 | [0.6, 3.1] | 1.8 | [0.7, 4.3] |
| 50 to 100 | 11 | 14,135 | 1.5 | [0.7, 3.0] | 2.7 | [1.3, 5.7] |
| *10 to 100[7]* | *40* | *46,438* | *1.6* | *[0.9, 2.8]* | *2.2* | *[1.2, 3.8]* |
| **Median house value[8]** | | | | | | |
| $100,000 to 787,100 | 23 | 22,350 | 1.0[6] | | 1.0[6] | |
| 75,000 to <100,000 | 12 | 22,194 | 0.5 | [0.3,1.0] | 0.5 | [0.2, 0.9] |
| 60,000 to < 75,000 | 10 | 14,735 | 0.6 | [0.3,1.4] | 0.6 | [0.3, 1.6] |
| 0 to <60,000 | 8 | 11,143 | 0.7 | [0.3,1.6] | 0.9 | [0.3, 2.3] |
| *0 to <100,000[9]* | *30* | *48,072* | *0.6* | *[0.3, 1.0]* | *0.6* | *[0.3, 1.1]* |

**Not Solid Waste Facility Free [n=251]**

| | | | Crude | | Adjusted[9] | |
|---|---|---|---|---|---|---|
| | #[2] | YEARS[3] | HR[4] | [95% CI][5] | HR | [95% CI] |
| **Percent non- white** | | | | | | |
| 0 to <10 | 28 | 740 | 1.0[6] | | 1.0[6] | |
| 10 to <20 | 17 | 545 | 0.9 | [0.4, 1.7] | 0.8 | [0.4, 1.7] |
| 20 to <30 | 18 | 380 | 1.1 | [0.6, 2.2] | 1.1 | [0.6, 2.2] |
| 30 to <50 | 16 | 322 | 1.4 | [0.8, 2.5] | 1.1 | [0.5, 2.5] |
| 50 to 100 | 22 | 388 | 1.4 | [0.9, 2.4] | 1.0 | [0.5, 2.1] |
| *20 to 100[11]* | *56* | *1,091* | *1.4* | *[1.0, 2.1]* | *1.2* | *[0.8, 2.0]* |
| **Median house value[8]** | | | | | | |
| $100,000 to 787,100 | 18 | 634 | 1.0[6] | | 1.0[6] | |
| 75,000 to <100,000 | 44 | 790 | 1.8 | [1.1, 3.0] | 1.4 | [0.8, 2.4] |
| 60,000 to < 75,000 | 26 | 583 | 1.5 | [0.8, 2.7] | 1.3 | [0.7, 2.4] |
| 0 to <60,000 | 13 | 368 | 1.2 | [0.6, 2.5] | 1.0 | [0.5, 2.2] |
| *0 to <100,000[9]* | *83* | *1,741* | *1.6* | *[1.0, 2.6]* | *1.3* | *[0.8, 2.2]* |

1. Adjusted for population density; 2. Number of block groups that received at least one permitted solid waste facility; 3. Block group-years contributed over time at risk for first solid waste facility permit; 4. HR: Hazard ratio; 5. 95% confidence interval [CI] based on standard errors computed with robust sandwich estimate; 6. Referent group; 7. Results obtained from separate model to summarize less white block groups compared to white block groups; 8. Median house value for specified owner-occupied housing units, adjusted for inflation to 2000 US dollars; 9. Results obtained from separate model to summarize less wealthy block groups compared to high-wealth block groups; 10. Adjusted for population density, region, distance to urban area; 11. Results obtained from separate model to summarize less white block groups compared to white block groups, referent group is 0 to <20% non-white.

**Table 6.3: Associations between first permitted solid waste facility and combined race and wealth, by presence of any previous solid waste facility: North Carolina block groups, 1990-2003**

**Solid waste facility free block groups [n=5,059]**

| | CRUDE | | | | | | ADJUSTED[1] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | < 10% non-white | | | >= 10% non-white | | | < 10% non-white | | >= 10% non-white | |
| **Median house value[2]** | **#[3]** | **HR[4]** | **[95% CI][5]** | **#** | **HR** | **[95% CI]** | **HR** | **[95% CI]** | **HR** | **[95% CI]** |
| **$100,000 to 787,100** | 8 | 1.0[6] | | 15 | 1.9 | [0.9, 4.1] | 1.0[6] | | 2.4 | [1.1, 5.1] |
| **0 to <$100,000** | 5 | 0.5 | [0.2, 1.5] | 25 | 1.0 | [0.5, 2.0] | 0.4 | [0.2, 1.3] | 1.2 | [0.6, 2.5] |

**Block groups with previous solid waste facility [n=251]**

| | CRUDE | | | | | | ADJUSTED[7] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | < 20% non-white | | | >= 20% non-white | | | < 20% non-white | | >= 20% non-white | |
| **Median house value[2]** | **#[3]** | **HR[4]** | **[95% CI][5]** | **#** | **HR** | **[95% CI]** | **HR** | **[95% CI]** | **HR** | **[95% CI]** |
| **$100,000 to 787,100** | 9 | 1.0[6] | | 9 | 1.8 | [0.7, 4.4] | 1.0[6] | | 1.6 | [0.7, 3.8] |
| **0 to <$100,000** | 36 | 1.8 | [0.8, 3.8] | 47 | 2.2 | [1.0, 4.9] | 1.6 | [0.7, 3.3] | 1.7 | [0.7, 4.0] |

1. Adjusted for population density; 2. Median house value for specified owner-occupied housing units, adjusted for inflation to 2000 US dollars; 3. Number of block groups that received at least one permitted solid waste facility; 4. HR: Hazard ratio; 5. 95% confidence interval based on standard errors computed by robust sandwich estimate; 6. Referent group; 7. Adjusted for population density, region, and distance to urban area.

**Table 6.4: Associations between first permitted solid waste facility and race and wealth, by owner/operator of solid waste facility: North Carolina block groups, 1990-2003**

**Private Solid Waste Facility [1]**

| | | | Crude | | Adjusted[2] | |
|---|---|---|---|---|---|---|
| | #[3] | YEARS[4] | HR[5] | [95% CI][6] | HR | [95% CI] |
| **Percent non- white** | | | | | | |
| 0 to <10 | 10 | 24,627 | 1.0[7] | | 1.0[7] | |
| 10 to 100 | 48 | 47,813 | 2.4 | [1.2, 5.0] | 2.4 | [1.0, 5.8] |
| **Median house value[8]** | | | | | | |
| $100,000 to 787,100 | 17 | 22,810 | 1.0[7] | | 1.0[7] | |
| 0 to <100,000 | 41 | 49,630 | 1.1 | [0.6, 2.2] | 0.9 | [0.4, 1.9] |

**Public Solid Waste Facility [9]**

| | | | Crude | | Adjusted[2] | |
|---|---|---|---|---|---|---|
| | #[2] | YEARS[3] | HR[5] | [95% CI][6] | HR | [95% CI] |
| **Percent non- white** | | | | | | |
| 0 to <10 | 29 | 24,627 | 1.0[7] | | 1.0[7] | |
| 10 to 100 | 59 | 47,813 | 1.1 | [0.7, 1.6] | 1.0 | [0.6, 1.8] |
| **Median house value[8]** | | | | | | |
| $100,000 to 787,100 | 22 | 22,810 | 1.0[7] | | 1.0[7] | |
| 0 to <100,000 | 66 | 49,630 | 1.3 | [0.8, 1.9] | 0.8 | [0.5, 1.1] |

1. Private solid waste facility: first permit issued in block group is owned and / or operated by private company or military; 2. Adjusted for presence of any solid waste facility in block group on January 1, 1990, population density, distance to nearest urban area, distance to nearest major road, and region; 3. Number of block groups that received at least one permitted solid waste facility; 4. Block-group years contributed over time at risk for first solid waste facility permit; 5. HR: Hazard ratio; 6. 95% confidence interval [CI] based on standard errors computed with robust sandwich estimate; 7. Referent group; 8 Median house value for specified owner-occupied housing units, adjusted for inflation to 2000 US dollars; 9. Public solid waste facility: first permit issued in block group is owned and operated by government entity.

**Table 6.5: Associations between first permitted solid waste facility classified as municipal solid waste landfill or construction and demolition debris landfill, and average waste disposed by county of origin: North Carolina block groups, 1990-2003**

| | | | Crude | | Adjusted[1] | |
|---|---|---|---|---|---|---|
| | #[2] | YEARS[3] | HR[4] | [95% CI] | HR | [95% CI] |
| **Average county waste [tons] disposed per person[5]** | | | | | | |
| Low [0.32 to <0.86] | 10 | 9,128 | 1.1 | [0.6, 2.0] | 0.6 | [0.3, 1.3] |
| Medium [0.86 to <1.16] | 32 | 32,909 | 1.0[6] | | 1.0[6] | |
| High [1.16 to 2.49] | 25 | 30,402 | 0.8 | [0.5, 1.4] | 1.2 | [0.6, 2.1] |

1. Adjusted for presence of any solid waste facility in block group on January 1, 1990 and block group population density; 2. Number of block groups received first permitted solid waste facility that was a municipal solid waste landfill or construction and demolition debris landfill; 3. Block-group years contributed over time at risk for first solid waste facility permit; 4. Standard error computed by robust sandwich estimate; 5. Average waste disposed per person is computed as the tons of waste disposed by county of origin over fiscal years 1991-2004 divided by the county population over fiscal years 1991-2004. Tons of waste include municipal solid waste and construction and demolition debris waste, measured at the county level; 6. Referent group.

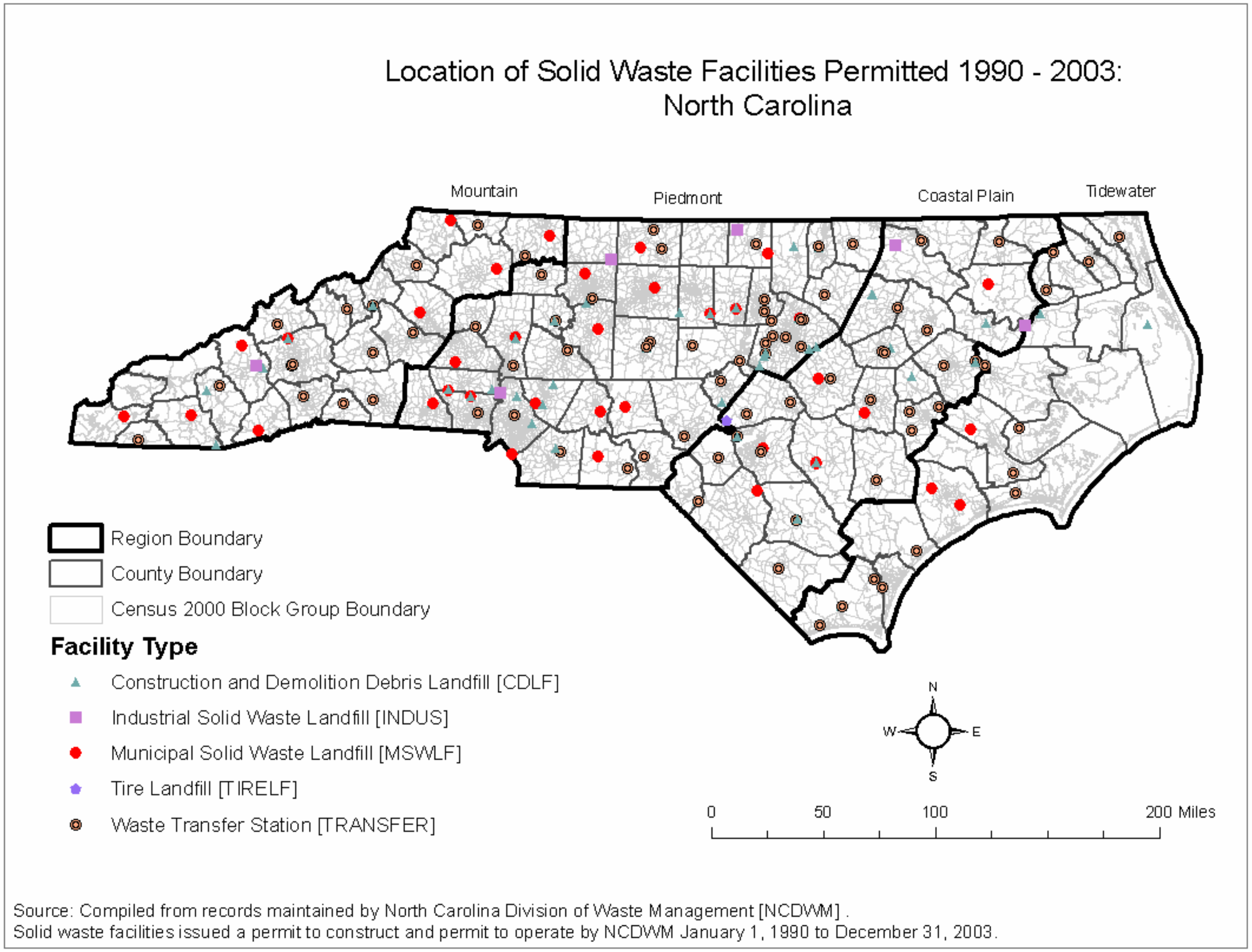


**Figure 6.1: Location of solid waste facilities permitted 1990-2003, North Carolina**

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# CHAPTER 7

# DISCUSSION

## A. Summary of key findings

The results of this research suggest that on average in North Carolina, solid waste facilities are more prevalent in non-white block groups compared to white block groups, and low-wealth block groups compared to high-wealth block groups, accounting for population density and region. The rate of solid waste facilities permitted between 1990-2003 is greater in non-white block groups than white block groups, accounting for population density. The comparison of the mean percent non-white population in block groups before and after new solid waste facilities were permitted suggest that ‘minority move-in’ does not explain the relationship between solid waste facility location and race of the block group.

This was one of the few studies that examined environmental justice concerns relating to solid waste management. These results are consistent with a statewide analysis in Massachusetts that found higher concentrations of solid waste landfills and transfer stations in non-white and low-income towns compared to white and high-income towns (5).

## B. Strengths and limitations

This research provides a conceptual model that can be used by other researchers to explore relationships between health and environmental injustice. This research could not have been completed without a review of solid waste facility records maintained by the NCDWM. More than 500 solid waste facility records were reviewed and available information was recorded and entered into an electronic database. The record review component of this research is an important contribution. This database will be shared with NCDWM and community groups so they may have easier access to this public information for future reference. Despite the review, some important questions could not be fully addressed due to the lack of information available from the records. For example, size of the facilities were not consistently available. Information on the time of solid waste permit was used as a proxy for time of solid waste facility siting. Siting decisions are made at the local level, and it was not feasible to obtain this information for a statewide analysis.

This research relied on census defined block groups. Block groups do not reflect community boundaries. Although on average, block groups are small compared to census tracts, intra-block group race and wealth characteristics may differ due to residential segregation patterns by race and wealth. A spatial coincident method was used to define prevalence and occurrence of solid waste facilities in block groups. Using this method does not account for boundary effects that may be present.

## C. Connection to broader themes

The local example of Holly Springs described in Chapter 1 provides a useful bridge to connect to broader themes. The popular press provides a useful source to identify some of the key issues that have emerged in landfill debates, as these quotes exemplify:

> The argument in favor of the new landfill has been that the county should keep its trash at home, mainly for cost reasons. But as Holly Springs has mushroomed into one of the state's fastest-growing towns, the logic of using increasingly valuable land there for a dump has been undercut…Many Eastern North Carolina counties are considering large regional landfills as a way to stimulate their sagging economies. Hauling Wake's garbage across county lines would present environmental, cultural, financial and transportation

> concerns that would have to be addressed. But if the end result made both counties better places to live, it is a trade off well worth exploring (4).

> ‘If it were your town, and you had a beautiful piece of property on the bypass, surrounded by a new subdivision with a golf course, swimming pool and all the amenities, how excited would you be to build a dump right in the middle of it?’ (2).

A few key points can be made in reference to the opinions expressed above. Both quotes imply that wealthy areas should not be considered for landfills. By this logic, only less wealthy areas could even be considered as potential landfill sites, thereby exacerbating environmental injustice concerns. This may further impede incentives for waste reduction since the consequences of waste disposal are placed further out of sight, and out of mind.

The trade-off suggested by the first quote raises some contradictions in the economic development argument that is often used to promote landfills in a community. In the Holly Springs/ Wake County example, the trade-off appears to be that Wake County residents pay a little extra for the cost of shipping waste out of the county and residents of another county ‘benefit’ from receiving this waste. This begs the question, if landfills are so beneficial, then why isn’t the golf course community excited about this economic development prospect? Instead, recent efforts by the current mayor of Holly Springs attempted to bring economic development to the land proposed for the landfill in the form of a pharmaceutical plant or shopping mall (1). Landfills as a viable economic development option seems to only apply to eastern North Carolina, a region of the state that on average is home to a larger proportion of non-white residents and is less wealthy than other regions of North Carolina.

These recent news accounts have focused on the prosperous Holly Springs, where many residents moved into expensive homes near golf courses after the landfill siting decision was made. The African-American neighborhoods of Feltonsville and

Easton Acres, where houses are modest by comparison, have lived next to a landfill since 1974.

While siting decisions are local, they are part of a bigger system involving our societal values. It is almost unquestioned that we live in a throw-away society, where waste is easily disposed in landfills, without consideration of present and future consequences of that disposal on water and air resources and public health.  Not only are the products that become waste commodities, but waste itself is a commodity to be traded, or dumped on communities perceived to have less influence to prevent it, or communities so desperate for any income that they accept the hazards associated with waste disposal along with the 'benefits'.  As Bullard writes "…should one part of society [the affluent] pay another part of society [the disadvantaged] to accept risks that others can afford to escape" (3).   While it is beyond the scope of this dissertation to address these larger questions, it is nonetheless important to raise the issues and to encourage useful dialogue that ultimately will result in improved public health.

### D. Policy implications

This research is completed at a time when North Carolina state legislators have proposed a moratorium on new landfill permits until the issue can be further evaluated (6). As this issue is debated in the public policy forum, the results of this research should be considered so that non-white and low-wealth communities in North Carolina are not faced with the continued disproportionate burden of solid waste facilities.  As discussed in Chapter 2, solid waste landfills were used as a *starting* point to describe the connections between solid waste, environmental injustice and health. This point is worth re-emphasizing here.  As landfill issues are debated, it is important that the connections between landfills and solid waste production, geographic scale, and the built environment are discussed.  This will require effort at all levels of government to address ways to reduce solid waste production and improve social and economic conditions for all communities so that landfills are not the only economic development option for less wealthy areas.

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## APPENDIX

Record review data abstraction form

Completed By:______________________________________ Date: ___/___/______

Facility Type: **«FacilityType»** Permit #: **«PERMIT_NUM»** Unique P#: «uniqp»

Facility Name: «SITENAME» ID #: «ID_NUM»

Facility Address (1): «SITEADDRES»
Street # Street Name Street Type Direction

Town (1): «SITECITY» Zip code: ______________ County: «COUNTY»

Facility Address (2): «Address_2»
Street # Street Name Street Type Direction

Town (2): «City2» Zip code: «Zip2»

***Facility Address (3):*** ______________________________________
Street # Street Name Street Type Direction

***Town (3):*** ______________________ ***Zip code***: ______________________

In CGIA: «incgia» In BA: «in_ba» In SC: «insc»

Coordinates in record? ☐ No ☐ Yes

Lat (Y) ______________________

Long (X) ______________________

Units:
☐ Decimal degrees
☐ Degree, minutes, seconds
☐ UTM _______(zone)
☐ State Plane ___ meters __feet
☐ Not specified
☐ Other _____________

Source of coordinates: ______________________________________

Tax Record: Block: ________ Lot: __________ Deed Book: __________ Page #: ________________

Driving Directions: ______________________________________

______________________________________

______________________________________

______________________________________

Site History and Land Use:

Other landfill facility at this location?
☐ No
☐ NS
☐ Yes Permit Num ______ Type__________ Name __________________ Status ________
Permit Num ______ Type__________ Name __________________ Status ________

Comments:

Source: North Carolina Division of Waste Management Records

Completed By:______________________________ Date: ____/____/______

Facility Type: «FacilityType» Permit #: «PERMIT_NUM»

Status: **«STATUS»** Date PTC 1 ___/___/_____ Date closed: ___/___/_____

mm/ dd / yyyy mm/ dd / yyyy

| | Date | PTC/ PTO | Total design capacity (units) | Total facility acres | Total Landfill Acres | | | Source (date) |
|---|---|---|---|---|---|---|---|---|
| | | | | | AC | FP | NS | |
| original | | | | | | | | |
| amend- ments | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

***Waste permitted to come from:***

1 = within county only
2 = within city only
3 = within NC only
4 = within region (______________________________)
5 = out of state
6 = not specified
7 = other (______________________________)

Ownership «PU_PRIV» ***Owner:*** ______________________________

***Operator:*** ______________________________

Lined «LINED»

Comments

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