A Social-Ecological Model of The Impact of Environmental Toxins on Maternal Health: Durham Case Study

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Abstract

Previous epidemiological studies in Durham have identified geographic clustering of elevated levels of environmental toxins, such as lead and cadmium, in the blood of pregnant women. Communities of color and low-income communities experience a higher frequency and magnitude of exposure to harmful environmental toxins and hazards such as pollutants, pesticides, and carcinogens. Pregnant women who are exposed to elevated levels of harmful toxins have an increased risk of miscarriage, premature birth, birth defects, and low birthweight deliveries. This paper aims to build a social-ecological model to describe the relationship between exposure to environmental toxins and the effects on maternal health. Using data collected from an electronic survey, ethnographic observations, and a review of literature, this paper identifies factors of exposure in Durham, NC at the individual, interpersonal, community and institutional levels. The individual and interpersonal levels of the social-ecological model were constructed using survey responses from sixteen Durham residents. The survey assessed awareness and attitudes toward environmental toxins and their potential impact on health. Ethnographic observations were conducted at three community meetings in Durham. The community and institutional levels of the social-ecological model were constructed from ethnographic observations and reviewed literature. Based on research findings, two policy recommendations were developed to educate residents living in high-risk communities and increase care for pregnant women with elevated blood levels of environmental toxins.

Acknowledgments

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Background and Introduction

Environmental Justice is Reproductive Justice

Reproductive justice was introduced as a conceptual framework in the 1990s by feminist activist groups comprised of indigenous women, women of color, and transgender individuals in the United States who recognized that the term extended beyond the pro-life and pro-choice debate.[1,2] As described by reproductive justice pioneer, scholar, and coauthor of Undivided Rights: Women of Color Organize for Reproductive Justice, Loretta Ross, "Our ability to control what happens to our bodies is constantly challenged by poverty, racism, environmental degradation, sexism, homophobia, and injustice in the United States."[2] In understanding that these complicated systems of overlapping forms of oppression influence an individual's experience regarding their reproductive health – then "reproductive justice" can be understood as having an emphasis not only on the ability to choose what happens to one's body, but also the level of access to reproductive care and assurance of reproductive wellbeing.

Reproductive justice, in addition, is based on the human right to personal autonomy and asserts the obligation of the government to ensure that the conditions are suitable for implementing one's decisions regarding their reproductive health. The three guiding principles of reproductive justice include: 1) The right not to have a child, 2) The right to have a child, and 3) The right to parent children in safe and healthy environments.[3,4]

The third principle of reproductive justice specifically describes the need for equitable access to resources such as quality health care, housing, education, a living wage, and a healthy environment. Complex intersectional inequalities often coexist to create barriers to a healthy living environment and may result in hazards existing in the physical environment. Research supports that communities of color and low-income communities experience a higher frequency and magnitude of exposure to environmental toxins and environmental hazards such as pollutants, pesticides, and carcinogens.[5-7] For women living in low socio-economic communities, these exposures may lead to poorer maternal health outcomes, and ultimately result in reduced health outcomes, disease, or illness for their children.[5,7-13]

The United States Environmental Protection Agency (EPA) defines environmental justice as the "fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies."[14] Environmental justice is achieved when two

objective goals are met. The first objective is for all individuals to have the same degree of protection from environmental and health hazards in their community. The second, for all individuals to have equal access to the decision-making process to have a healthy environment. To ensure the right to parent children in safe and healthy environments, environmental justice must be achieved alongside reproductive justice.

Therefore, this study focuses on the effects of elevated exposures to environmental toxins, such as heavy metals, on maternal health and birth outcomes, specifically in Durham, North Carolina (NC). The disproportionate exposure of environmental toxins in low-income and minority communities and its potential to cause adverse health outcomes has been well studied.[6,15-17] Low birth weight deliveries account for 60-80% of neonatal deaths and half of all preterm births worldwide.[18] The United States has the highest infant mortality rates among industrialized countries.[19] As a result, women, and more specifically pregnant women, are a vulnerable population with a distinct set of risks that should be uniquely considered. In the United States, infant mortality and low birth weight disproportionality affect Black Americans and Americans with low socioeconomic status.[20,21] Low birthweight may cause decreased growth and neurodevelopment and an increased risk of chronic diseases later in life such as ischemic heart disease, hypertension, obesity, and anxiety disorder.[11,22,23] Most often communities with the greatest toxic burden can least afford care for these adverse health consequences, which emphasizes the need to analyze these maternal health outcomes through an environmental justice perspective.[6]

Social-Ecological Model as a Conceptual Framework

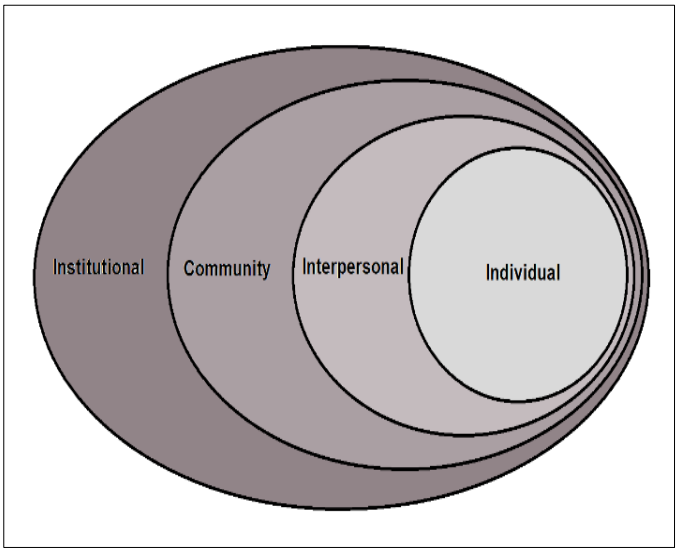
Previous studies on the effects of indoor environmental exposure on adverse health outcomes describe complex physical and social conditions that influence the susceptibility to increased exposure to environmental toxins.[13,24,25] No single factor explains why some communities have increased levels of environmental toxins compared to other communities. Investigators from these referenced studies suggest a variety of interventions to address these hazards, including community education programs and improved housing policies. However, since there is no single cause for increased exposure to environmental toxins in certain communities compared to others, there is no single solution to achieve environmental equality and thereby reducing harmful impacts on maternal and child health. Therefore, this study uses a social-

ecological model approach to understand the intersecting factors involved in the relationship between maternal and child health and environmental toxins.

The social-ecological model is a framework used to examine the physical and social contexts of individuals' environments.[26] There are four levels presented in the social-ecological model that categorizes the dimensions of people's environments: individual, interpersonal, community, and institutional (*see* ***Figure 1***). The individual level consists of characteristics of an individual that influence behavior such as knowledge, attitudes, or identity. The interpersonal level includes the social networks and support systems that influence an individual's behavior, such as family and friends. The community level is comprised of the relationships among organizations, businesses, and institutions that affect how services are provided to an individual. Lastly, the institutional level contains the laws and policies that regulate operations and the allocation of resources.

The social-ecological model integrates strategies from both behavioral and environmental-based health promotion programs and practices.[27] This intersectional emphasis permits a closer examination of the multifaceted factors and impacts that environmental toxins have on maternal and child health outcomes, and offers a path for future interdisciplinary evironmental and reproductive justice programs and interventions.

Figure 1. *Social-ecological Model*



Durham as a Case Study

Recent scientific and political events have positioned Durham, NC as a suitable focus for a case study.[28-31] Durham is located between three prominent research institutions that form the Research Triangle Park (RTP): Duke University, North Carolina State University, and the University of North Carolina at Chapel Hill. Due to its proximity to these research and education

institutions, Durham has consistently been the focus of epidemiological studies on environmental toxins and maternal health.[32-37] Findings from these studies provide evidence of neighborhood clustering of elevated levels of environmental toxins and their potential relationship to adverse maternal and child health outcomes.

Between 2000 - 2010, Durham experienced a population growth of 22%.[38] In 2018, Durham's population reached to an estimated 316,739 people.[39] Durham's rapid population growth continues to transform the housing needs of the city. Local government officials and Durham residents have focused their attention to the issues of affordable housing, housing options, and gentrification.[29,40,41] This research was conducted at an opportune time to examine how environmental health and reproductive justice can be incorporated into the discussions of equitable and affordable housing.

Methods

A mixed-methods approach was used to determine and understand the different factors involved at each level of the social-ecological model, and their potential impact on maternal and child health outcomes. Data was collected through an online survey and ethnographic observations conducted at three community meetings in Durham. To supplement these primary data collected, a literature review was used to determine additional individual, interpersonal, community, and political factors involved in the potential relationship between environmental toxins and maternal and child health outcomes. An ethics waiver was obtained from the North Carolina State University's Institutional Review Board for this research.

To examine the individual and interpersonal levels of the social-ecological framework, data on the awareness of and attitudes regarding environmental toxins and the relationships these toxins may have on the health of individuals was collected through an online survey. The online survey was programmed in Qualtrics, an online management platform that provides a secure web-based survey tool to conduct survey research, evaluations and other data collection activities. Potential participants were recruited at local community events, through word-of-mouth, as well as through online Durham-focused forums. Recruitment flyers with the survey website link were provided to potential participants at community events and electronically. To be eligible to take part in the survey, individuals must have reported (1) being 18 years of age or older, and (2) currently residing in Durham. The survey was distributed and marketed over a 30-day time period. All potential survey participants were required to provide informed consent electronically. The survey was

completed on participant's personal devices. The survey contained questions regarding the current health of survey participants (e.g. "How would you rate your health status on a scale of poor to excellent?"), the awareness of environmental toxins (e.g. "Do you consider yourself well informed, somewhat informed, or not well informed about environmental toxins such as …?"), the attitudes towards the relationship between environmental toxins and health (e.g. "Are you or have you ever been concerned about your exposure to environmental toxins?"), and current health behaviors associated with a reduction in environmental toxin exposure (e.g. "Have you ever had your blood tested for environmental toxins such as lead?").

Data were also collected on community and institutional factors through ethnographic observations. The researcher attended three community meetings in November 2019, including one grassroots organization meeting to support the economic development in Durham's District 1, a police and community engagement meeting for residents of District 1, and a health and housing committee meeting at the Durham County Department of Public Health. Homes with elevated levels of cadmium and co-occurring metals such as lead, and barium were identified in District 1 in previous epidemiological studies[33-35]. The study researcher recorded detailed notes by hand during these meetings regarding the potential relationship between environmental toxins and adverse maternal and child health outcomes and potential barriers to education or access to health resources. Knowledge gained from ethnographic observations was used to identify and create community and institutional levels of the social-ecological model.

Table 1 Sample Characteristics

Characteristic	No. (%) of Participants (N=16)
Age	
18 - 24	2 (13)
25 - 34	5 (31)
35 - 44	5 (31)
45 - 54	0 (0)
55 - 64	4 (25)
Gender	
Female	12 (75)
Male	4 (25)
Race	
Black or African American	4 (25)
White	12 (75)
Highest level of education	
High school graduate or less	0 (0)
Trade school	0 (0)
Some college	1 (6)
Associate degree	2 (13)
Bachelor's degree	6 (38)
Master's degree or higher	6 (38)
I do not wish to disclose	1 (6)
Household annual income	
Less than $20,000	2 (13)
$20,000 to $34,999	0 (0)
$35,000 to $49,999	5 (31)
$50,000 to $74,999	4 (25)
$75,000 to $99,999	0 (0)
Over $100,000	4 (25)
I do not wish to disclose	1 (6)
Do you own or rent your home?	
Own	7 (44)
Rent	8 (50)
Do not wish to disclose	1 (6)
What is your zip-code?	
27701	4 (25)
27703	4 (25)
27707	3 (19)
27704	2 (14)
27712	2 (13)
27713	1 (7)

Results

The online survey received 22 response, however after removing ineligible respondents who reported being under the age of 18 or did not provide a Durham County zip code, the sample size included 16 individuals. Participant demographics are shown in **Table 1**. The majority of participants reported

being female (N=12), White (N=12), and having received some level of college education or higher (N=15). Respondent's ages ranged from 18 to 64. Household annual income levels ranged from less than $20,000 to over $100,000; 44% reported owning their own home compared with 50% of participants who rent, and 1 participant who did not wish to disclose. Half of the respondents reported living in either a 27701 or 27703 zip-code (N=8). **Table 2** presents participant responses regarding their awareness of environmental toxins.

Table 2 Awareness of Environmental Toxins

Question	**No. (%) of Participants (N=16)**			
Have you heard about the following toxins?	**Yes**	**No**	**Unsure**	**Did Not Respond**
Lead	16 (100)	0 (0)	0 (0)	1 (7)
Arsenic	16 (100)	0 (0)	0 (0)	1 (7)
Cadmium	7 (44)	7 (44)	2 (13)	1 (7)
Have you heard about any of these toxins existing in your community?	**Yes**	**No**	**Unsure**	**Did Not Respond**
Lead	7 (47)	7 (47)	1(7)	1 (7)
Arsenic	3 (20)	11 (73)	1 (7)	1 (7)
Cadmium	2 (13)	12 (80)	1 (7)	1 (7)

Participants reported being familiar with lead and arsenic, however, were less familiar with cadmium. Although participants were aware of these toxins, many did not hear of these toxins existing in their community or were unsure. All respondents who indicated "yes" to hearing of toxins existing in their community had either a 27701, 27703, or 27712 zip-code. Participants who indicated that they were aware of the existence of these toxins were asked where they learned about them (see **Table 3**). Participants were able to select more than one source of information for where they learned about the environmental toxins. The number of selected sources ranged from one to five. The median number of sources selected was two (Mean=2.4).

Table 3 Sources of Information

Where did you learn about any of the previously mentioned environmental toxins? Please select all that apply.	**No. (%) of Responses (N=35)**
Media (such as TV, radio, news, etc)	13 (37)
Social media (such as Twitter, Facebook, Instagram, etc)	5 (14)
Friends or family	5 (14)
Community event	5 (14)
Health professionals	6 (17)
Other, please specify	
School	1 (3)

A majority of respondents indicated that they learned about these toxins through various forms of media, including TV, radio, and other news sources. Participants were then asked survey questions related to their attitudes towards and beliefs regarding environmental toxins (see **Table 4**).

Table 4 Attitudes Towards Environmental Toxins

Question	No. (%) of Participants (N=15)			
Do you consider yourself well informed, somewhat informed, or not well informed about environmental toxins?	**Well informed** 3 (20)	**Somewhat informed** 5 (33)	**Not well informed** 7 (47)	**Did Not Respond** 1(7)
Do you believe exposure to environmental toxins can affect your health?	**Definitely Yes** 11 (73)	**Probably Yes** 4 (27)	**Might or might not/ Probably not/ Definitely not** 0 (0)	**Did Not Respond** 1(7)
Are you or have you ever been concerned about your exposure to environmental toxins?	**Yes** 7 (47)	**Maybe** 5 (33)	**No** 3 (20)	**Did Not Respond** 1(7)

A majority of participants (80%) reported having ever been, or potentially ever been, concerned about their exposure to environmental toxins. Twenty percent of participants reported being well informed about environmental toxins, whereas 80% of participants indicated being only somewhat informed or not well informed. When asked specifically about their concern about exposure in their homes, 50% of participants who rent responded "Yes" while only 30% of participants who own their homes reported "Yes".

Table 5 below shows participant's current habits that may be associated with reducing their potential exposure to environmental toxins, such as how often interior surfaces are cleaned with a disinfectant wipe or damp cloth. Twenty-five percent of participants reporting only cleaning surfaces once a month. Further, only three participants reported ever having their blood tested for exposure to environmental toxins, such as lead.

Table 5 Habits for Prevention

Question	No. (%) of Participants (N=16)					
How often do you clean your interior surfaces with a disinfectant wipe or damp cloth?	**A few times a week** 7 (44)	**Once a week** 3 (19)	**Less than weekly** 2 (13)	**Once a month** 4 (25)		**Did Not Respond** 1 (7)
How often do you take vitamin supplements?	**Daily** 5 (31)	**4-6 times a week** 1 (6)	**2-3 times a week** 2 (13)	**Once a week** 4 (25)	**Never** 4 (25)	**Did Not Respond** 1 (7)
Have you ever had your blood tested for environmental toxins, such as lead?	**Yes** 3 (19)	**Maybe** 2 (13)	**No** 11 (69)	**Did Not Respond** 1 (7)		

Discussion

Individual and Interpersonal Levels

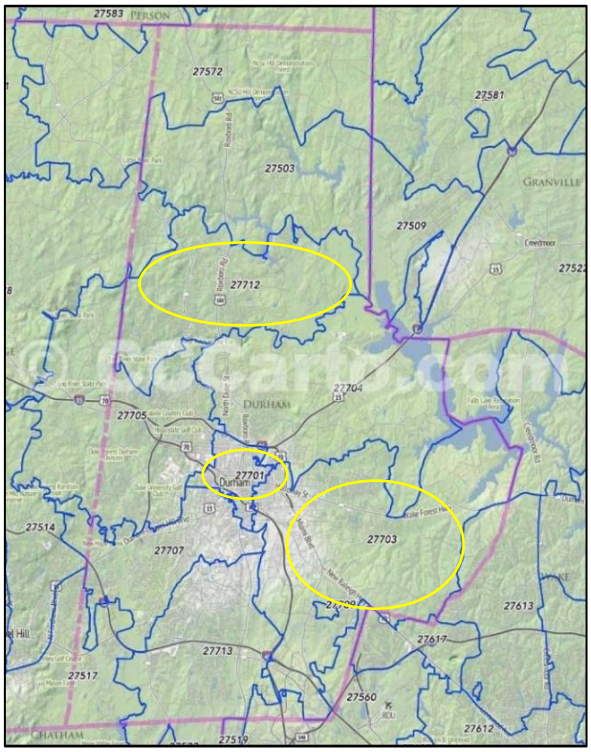
The individual level of the social-ecological model describes the relationship between environmental toxins and maternal health, based on the individual's biology, beliefs, and behaviors. Individual knowledge and beliefs are powerful influencers on practicing preventive behaviors. Although a majority of survey respondents believed environmental toxins can affect their health, only three respondents considered themselves well-informed about environmental toxins. Additionally, nearly half of survey participants reported being concerned about their exposure to environmental toxins and its impact on their health.

These harmful toxins accumulate in the body over time; therefore, harmful and noticeable effects may only present themselves after long-term exposure. Individuals can adapt certain practices to reduce their exposure to toxins in their own home. For example, cleaning countertops with a damp cloth has been shown to reduce the build-up of environmental toxins found in dust.[42] Further, eating a diet rich in iron, calcium, and vitamin C, or taking vitamin supplements, has been shown to reduce the body's heavy metal absorption.[43,44] Yet less than half of the survey respondents reported cleaning their interior surfaces a few times per week, and or taking supplements daily.

The interpersonal level of the social-ecological model describes the relationships and social networks of an individual, often comprised of friends and family, and its impact on an individual's behavior or actions. In this study, five survey respondents reported they learned about environmental toxins through their family or friends. Increasing awareness of environmental toxins among an individual's family members or friends may help to increase the level of preventative actions taken in the home. This may be especially important for friends or family members of a pregnant or parenting woman. In addition, to the potential harm that toxins can have on a pregnant woman, developing fetuses and infants may also suffer from life-threatening, or chronic diseases. Children with higher levels of toxin exposure are at an elevated risk for cognitive disorders, respiratory conditions, cancer, and cardiovascular disease.[9,10,45] Mothers are often a major influence on a child's physical environment and thereby exposure to potential toxins. By increasing awareness about these toxins and preventive steps to lessen the risk of harmful exposure among pregnant or parenting women, and their friends and families, the health of future

generations can be protected.

Image 1 Zip codes of survey respondents who heard of environmental toxins in their communities. Reprinted from CCCarto.com

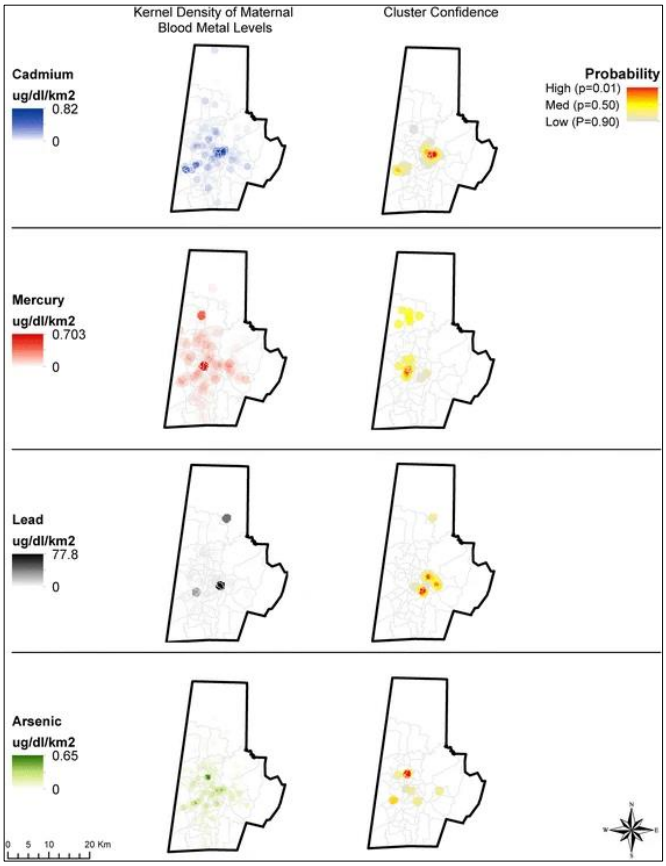


Community Level

Results from this study showed that less than half of survey respondents had heard of environmental toxins existing in their community. Respondents who were aware of toxins existing reported living in either a 27701, 27703, or 27712 zip-code. Residences with a 27712 zip-code are in the northern part of Durham county. The center of downtown area of Durham is located in the 27701 zip-code. The southeastern part of downtown Durham and most of the southeast part of the county has a 27703 zip-code **(Image 1)**. Previous epidemiological studies have identified certain neighborhoods in Durham to have higher levels of environmental toxins than others.[34,35,46] Graphs from a 2015 study estimate geographic clustering in regions with 27701, 27703, and 27712 zip-codes, with the highest confidence near downtown Durham (**Image 2**).[34] Cadmium and lead clustering had the highest probability in an area of downtown Durham in zip code 27701. According to census data, a majority of the residents living in this area of Durham reported being Black and having a median household annual income of $29,929.[47,48]

As previously mentioned, this study conducted ethnographic observations in community meetings with residents from the 27701 zip-code. At a grassroots economic development meeting, residents discussed barriers residents may face when attending an upcoming job fair. Residents evaluated methods for marketing from past year's job fair that included social media and door-to-door visits in communities owned by the Durham Housing Authorities (DHA). During the meeting, the group decided, in addition to the previous marketing efforts, the job fair should be advertised during Sunday church services. Transportation was another factor discussed. Residents may lack access to dependable transportation therefore the group discussed distributing bus passes. These

Image 2 Geographic clustering of elevated blood heavy metal levels in pregnant women



same barriers may also prevent residents from attending a health education workshop or from obtaining necessary health care. When targeting specific neighborhoods, public health interventions should be created with cognizance of the various sources of leadership in the neighborhood along with the social challenges faced by residents in order to create innovative and inclusive solutions.

During this community meeting, a resident suggested conducting a survey to understand what barriers exist in the community. However, this suggestion was rejected by the group. One resident explained that surveys "like the one suggested" are "always" conducted, however "nothing is ever done with them". During the police and community engagement meeting, two surveys were provided to meeting attendees. Although it is beneficial to conduct preliminary research about a target community before an intervention, vulnerable communities are frequently the subject of research studies, yet little action is taken after them. Residents in these communities may feel overburdened by excessive study participation or they may begin to lose trust in the scientific community if they do not see change as a result of the studies.

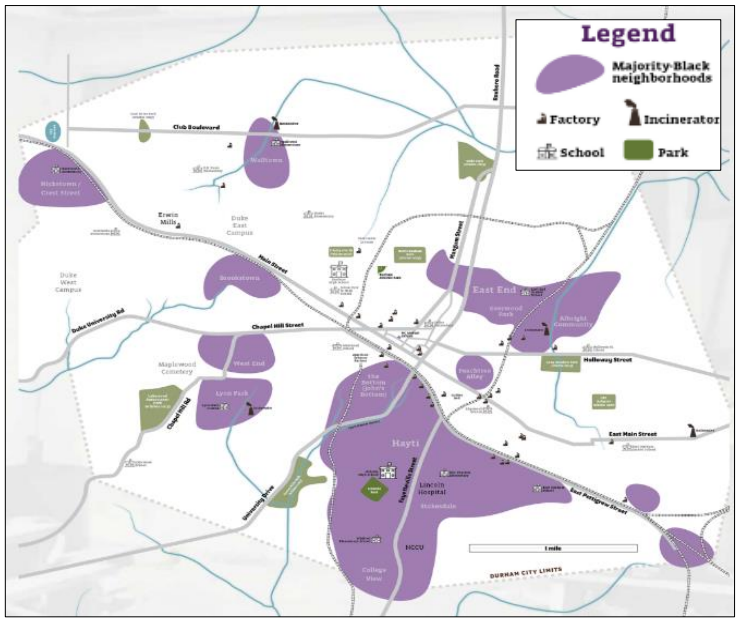
Additionally, residents' reported feelings of distrust due to previous toxic disasters in their communities or communities similar to theirs. One resident shared that she does not allow her family to consume tap water after the Flint Water Crisis, further explaining Black and low-income families are often exposed to such harmful toxins. In January 2020, a carbon monoxide leak in a DHA community was thought to be the cause of death of two infants and hospitalizations of 11 other residents.[49] In response to this event, one resident said, "We believe that people are being exposed to dangerous chemicals in their own homes. I think it's just a humanitarian issue. We

can't let our people live like this." A lack of communication and action between governmental officials and disadvantaged communities has led to fear around unknown health risks. Relationship building between governmental organizations and community leaders, or even individuals, may increase trust and reassurance in the safety of DHA neighborhoods. Education at the individual and interpersonal level may empower residents to protect themselves from the harmful effects of environmental toxins.

Institutional Level

The institutional level of the social-ecological model involves the federal, state, and local governmental actions that impact an individual's health, such as policies, resource allocations, and infrastructure. Historical and systemic factors influence the current institutions in Durham. Due to segregation, Black neighborhoods in Durham were categorized as having the poorest housing and neighborhood conditions.[50] During the 1930s, these neighborhoods were built closest to incinerators and factories (**Image 3**). [50] During the early 20th century, Durham was largely known for its tobacco manufacturing, however textile, lumber, automobile, machinery factories were also present in the area. Today, the area is known as the American Tobacco Compass in downtown Durham, inside the 27701 zip-code.[51] Increased proximity to factories and incinerators has been shown to be associated with increased exposure to poorer air quality and harmful debris containing heavy metals.[52-55] The two major sources of cadmium are ingestion of certain foods or cigarette smoking.[56] Studies have shown an association between secondhand smoke or exposure to tobacco smoke and increased levels of

Image 3 Black Neighborhoods Proximity to Factories and Incinerators, 1937



heavy metals.[57-59] The increased exposure to tobacco manufacturing may be a source of increased of heavy metals, specifically cadmium, in the soil of the surrounding area.

In the 1930s, the racial and economic segregation of Durham was maintained by redlining, a process in which banks refused to offer loans and mortgages, or offer worse rates to customers based on the racial composition of their neighborhood. The red areas on the Durham Home Owners' Loan Corporation map were largely Black communities, considered "too risky" for loans (**Image 4**).[60,61]

Image 4 The original Home Owners' Loan Corporation map of Durham, dated July 23, 1937 shows the redlined districts

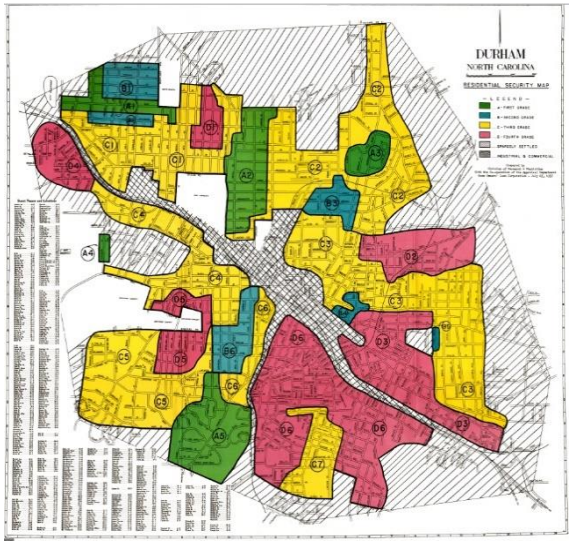
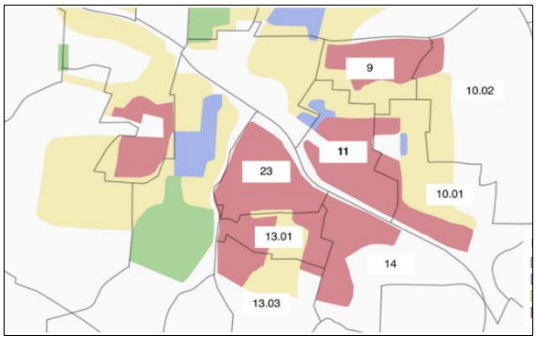


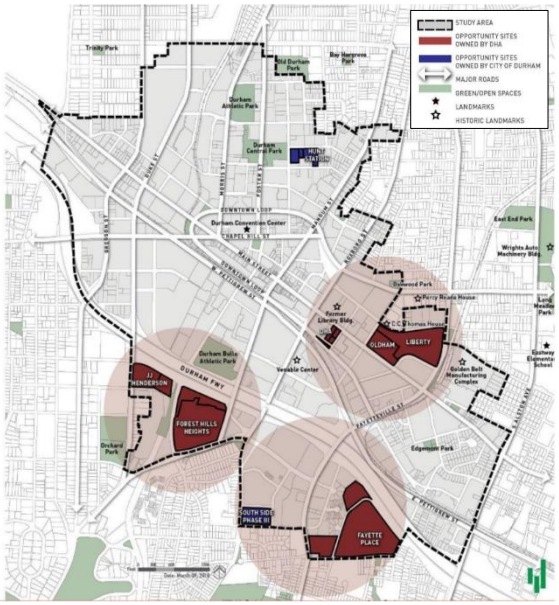
Image 5 Redlined Areas Mapped Over Modern Census Tracts



The effects of past policy decisions can be seen in the geography of poverty in Durham. As described in the *Community Level*, the 27701 zip-code has a majority of Black residents and the lowest median household income in the city.[47] **Image 5** shows census tracts overlap sufficiently with redlined areas, supporting the use of census data to analyze neighborhood characteristics.[62] Redlined tracts have a population of 73% Black residents. Tracts 11 and 14 have poverty rates over 50%. The least poor redlined tract (13.03) has a poverty rate 31% higher than the city overall. Median household income in the redlined tracts is a fraction of the city's and county's median income.[62] Due to the increase in population, affordable housing has become an urgent issue discussed by local Durham governmental officials.[29,40,41] Unsurprisingly, areas with the highest percentage of affordable housing include redlined tracts.[63] Neighborhoods identified to serve people with lower incomes may be exposed to higher health risks due to historical housing and environmental conditions.

The average year of residential construction in the redlined tracts is 1955, which is older compared to the county average of 1975.[47] A source study of lead and cadmium in Durham

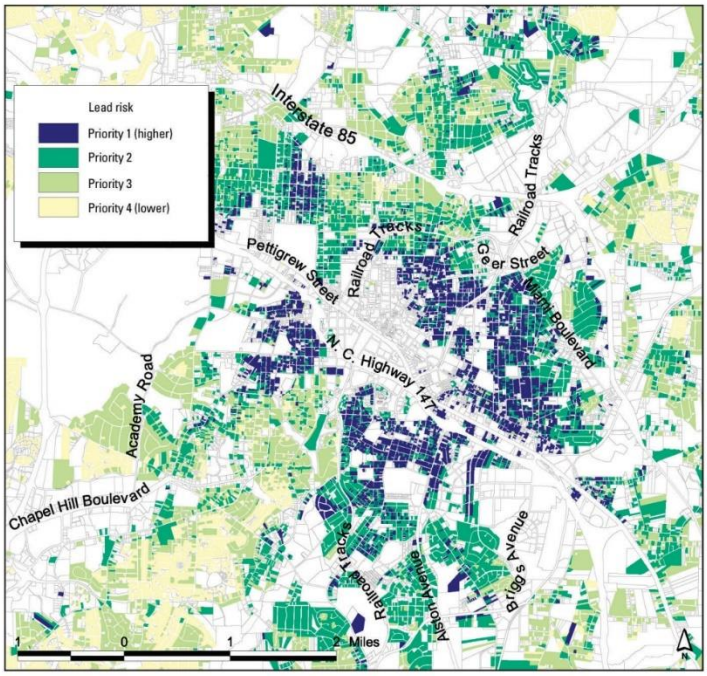
Image 6 Durham Housing Authority Communities in Downton Durham



found a correlation between the age of home, state of repair, and elevated blood levels the environmental toxins.[35] The majority of homes (68.1%) in geographic clusters of higher than normal levels of cadmium were constructed during or before 1959. Clustering of lead was found among homes built before 1978 with 52% built between 1960 and 1978. Homes in these lead and cadmium clusters received C and D rated state of repairs on a scale of A – E. The positive correlation between the age of homes and the level of environmental toxins has been repeatedly identified.[64-66]

Residents at the community meetings attended by the researcher held great concern for improving the quality of life for residents of the DHA. Five of the sixteen communities owned by the DHA have a 27701 zip-code and are near the American Tobacco Campus (**Image 6).**[67] The DHA oversees 1,396 subsidized homes and apartments. In Durham County, 79% of DHA housing units have a female head of household and 48% of all units have a female head of household and children.[68] This high proportion of women and children in the DHA shows the need for women's health and reproductive justice to be at the forefront of providing clean and safe living environments. Past policies of segregation and redlining have made race and poverty institutional factors in the risk of heavy metal exposure. Using census data and blood testing records, a team of researchers predicted the geographic area of elevated lead levels (**Image 7**).[69] They

Image 7 Lead risk priorities mapped for Durham, North Carolina



found three factors - race, poverty, and age of home - to have the most power for predicting high lead risk areas.

Current laws and regulations exist to monitor and identify children with elevated blood levels of lead at the state and local level. State policies encourage health care providers to conduct blood testing on all children 12 months of age and again at 24 months of age.[70,71] All children participating in Medicaid or the Special Nutrition Program for Women, Infants and Children (WIC Program) are required to receive a blood lead test at 12 and 24 months of age. The NC Department of Health and Human Services recommends testing if a child lives in a zip-code identified as high-risk. In Durham, the 27701 zip-code is the only area identified as high-risk. If a child is found with a blood lead level (BLL) of more than 5 μL/dL an environmental investigation is conducted.[71] Additionally, in 2012, the blood lead action level (BLAL) for children in North Carolina was lowered from 10 μL/dL to 5 μL/dL.

State policies focused on the protection from lead and other environmental toxins began with concern for child health. In 2017, a policy was adapted to include protecting pregnant women. The Centers for Disease Control and Prevention (CDC) does not recommend blood testing for all women; however, the CDC recommends universal blood screenings of pregnant or lactating women in known high-risk geographic areas.

Beginning in July 2017, any pregnant woman in North Carolina with a twice confirmed consecutive blood lead level at or above the BLAL became eligible for a free environmental health assessment by environmental health specialists. In addition, in July 2018, North Carolina began providing lead testing at no charge for women tested at local health departments. The North Carolina Lead and Pregnancy Risk Questionnaire is a risk assessment tool used by health providers to identify women who should be screened for lead exposure.[71] Prenatal care providers are also required to refer patients to receive an environmental health assessment if elevated blood lead levels are detected. If a home is found with lead hazards, then remediation is required.[72] *Additiona*lly, the public health department will, in writing, advise the owner or managing agent of the home and the woman or child's guardian of the importance of carrying out routine cleaning activities. The cleaning activities include the following:

1) Wiping clean all windowsills with a damp cloth or sponge at least weekly.

2) Regularly washing all surfaces accessible to children.

3) In the case of a leased residential housing unit, identifying any deteriorated paint in the unit and notifying the owner or managing agent of the conditions within 72 hours of discovery.

4) Identifying and understanding potential lead poisoning hazards in the environment of each child less than six years of age and each pregnant woman in the unit (including toys, vinyl miniblinds, playground equipment, drinking water, soil, and painted surfaces), and taking steps to prevent children and pregnant women from ingesting lead such as encouraging children and pregnant women to wash their faces and hands frequently and especially after playing outdoors.

As a result of the increasing population in Durham and lack of affordable housing, new housing policies are being formed and current housing programs are being reevaluated. In August 2018, the Durham Public Health Department formed a Health and Housing Committee to ensure the health of its residents is included in the decision-making process of improving housing conditions in Durham.[73] In the committee's 2018-2021 Community Health Improvement Plan, three main goals are outlined: obtain, maintain, an synthesize health-related data that can be used for housing decisions; educate Durham residents and organizations on how to access housing related resources; and increase awareness about the relationship between health and housing.[74] To meet the third goal, the committee plans to train health and housing ambassadors who will be able to communicate health and housing data to residents and advocate for the importance of considering health in discussions about housing policies.

Study Limitations

This research provides important data and information regarding the high-risk of exposure to environmental toxins to residents in Durham, NC, and especially among pregnant or parenting women, and children. However, limitations such as the small sample size and limited diversity of survey respondents does exist. These constraints may limit the generalizability of study findings to the larger population of Durham and similar communities. In an effort to reduce these constraints, the researcher conducted supplemental ethnographic observations by attending Durham community meetings and conducting a literature review regarding the exposure to environmental toxins, neighborhood clustering, historical infrastructure and zoning plans, and previously conducted studies in Durham.

Conclusion

In an effort to protect the health of women and their children from exposure to harmful environmental toxins, the social-ecological model was be used to identify factors at each of the four levels that lead to potential increased exposure, as well as opportunities for actionable solutions. This research presents an analysis of the collective influences on maternal and child

health that can be used to develop public health interventions and actions to ensure the equal degree of protection for all women in Durham from environmental toxins.

Policy Recommendations

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1. Implement Public Health Campaigns Targeted for Residents in High-Risk Communities in Durham, NC

Individuals can make choices and develop habits to reduce their risk of exposure to environmental toxins. The majority of survey respondents did not feel well informed about environmental toxins or did not proactively address potential exposure, such as through regular cleaning or undergoing blood testing. To increase the awareness of the potential health risk and knowledge of prevention methods, workshops and educational materials should be provided to families living in high-risk neighborhoods. The 2018 - 2021 Community Improvement Plan of Durham Public Health Department's Health and Housing committee presents an opportunity to provide in-person workshops. Health and housing ambassadors can be trained on educating neighborhoods in high-risk areas on actions to protect themselves from exposure with specific information for pregnant women. Partnerships between Durham Public Health Department and community-based organizations, like Partnership Effort for the Advancement of Children's Health (PEACH) Durham, can strengthen the reach to vulnerable communities by increasing resources and leveraging relationships with trusted community leaders. Empowering communities to protect their health can reduce the toxic burden accumulated throughout their lifetime.

Education programs focused on environmental toxins may help to inform Durham residents about the sources of heavy metals, their impact on an individual's health, and simple actions that can be taken to prevent or reduce exposure. PEACH is a local nonprofit organization in Durham that provides workshops on lead hazards to the public.[75] PEACH is the only organization in Durham to provide regularly scheduled workshops to residents, however due to the limited number of available staff and funding limitations, it is not feasible for PEACH to provide such services to all residents that could be potentially at-risk for exposure to environmental toxins. As the largest public health entity in the area, the Durham Public Health Department should provide lead hazard workshops to community members, specifically mothers, pregnant women, or families with young children.

Additionally, city-wide public health education campaigns about potential health hazards from environmental toxins can help to inform residents about preventive actions and change the attitudes towards the impact of heavy metals on individual health. A study evaluated a city-wide effort lead-poisoning awareness campaign in Hartford, Connecticut.[76] The campaign involved several elements including billboards, newspaper advertisements, an art display, and a postmark. As a result of the campaign, 45% of study sample reported taking steps to prevent lead-poisoning because of one of the campaign components. Similar effectiveness was seen in an evaluation of a New York City media campaign focused on lead-poisoning.[77] The campaign in New York City ran for three years. Each year, researchers saw an increase in knowledge about lead-poisoning. By increasing awareness of the health risks from exposure to environmental toxins, Durham residents can take action to protect themselves from potential exposure.

Therefore, to increase the awareness of these preventive practices among residents living in high-risk areas in Durham, the Durham Public Health Department in partnership with the Durham Housing Authority (DHA) should lead a robust public health campaign utilizing social media and print marketing materials, specifically adapted to reach individuals and families living in the high-risk areas. Educational materials sharing the symptoms of exposure to these toxins and how to protect their health and their family's health should be provided directly to residents living in DHA communities. Targeted approaches may include distributing electronic information via zip-code specific ads on social media, email, internet browsers, as well as the physical mailing of posters, brochures, and pamphlets to residents. Posters may also be displayed within commercial areas surrounding the high-risk areas in Durham (e.g., the impact exposure may have on pregnant or parenting women, newborn or developing children).

2. Encourage Health-Care Providers to Recommend Blood-Testing for Pregnant Women Living in High-Risk Areas in Durham, NC

Identical blood lead levels in pregnant women are passed along to their developing baby as lead freely passes through the placenta. There is no safe blood lead level for children. According to the CDC, even low levels of lead in blood have been shown to affect IQ, ability to pay attention, and academic achievement. The CDC recommends universal blood lead level testing on all children below 72 months of age. In NC, children living in high-risk zip code areas are required to undergo blood lead level testing. However, universal blood testing for pregnant women is not

recommended by the CDC. Instead, health care providers for pregnant women conduct a question-based assessment to determine whether blood lead testing is required. Identifying and abating the negative impacts of potential lead exposure early on during pregnancy will protect the mother and the child's health and future lifetime health. **Therefore, regardless of responses to the question-based assessment, health care providers should recommend routine blood lead testing for women living in high-risk zip codes in Durham, NC at prenatal appointments.**

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