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USING GEOGRAPHIC INFORMATION SYSTEMS TO ASSESS RISK FOR ELEVATED BLOOD LEAD LEVELS IN CHILDREN IN KALAMAZOO COUNTY, MICHIGAN

by

Amatun Noor

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Master of Arts
Department of Geography

Western Michigan University
Kalamazoo, Michigan
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2006

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It is difficult to express my gratefulness in words to the people who have made me what I am today. I do believe that the environment that we live in influences us more than anything. First of all I like to acknowledge the Geography Department of Western Michigan University for providing me the best facilities and an atmosphere to gain and share knowledge with the faculty and the students. To be more specific I would like to thank Dr. Gregory Veeck who was more like a local guardian to me than a supervisor. Also, I would like to thank Dr. Lisa DeChano, Dr. James Biles and Dr. Kathleen Baker for supporting me in every step of my thesis. My interests in Childhood Lead Poisoning became a reality when I was fortunate enough to work with Ms. Annie Wendt, Epidemiologist of Kalamazoo County Health and Community Services Department.

My thesis would be incomplete just like my life if I did not thank my life partner Mustafa. Without the blessings of my parents, in-laws, relatives and last but not the least of all my friends, I could not have completed my thesis. Also I am always grateful to God for giving me this opportunity to study in the United States.

Amatun Noor

USING GEOGRAPHIC INFORMATION SYSTEMS TO ASSESS RISK FOR ELEVATED BLOOD LEAD LEVELS IN CHILDREN IN KALAMAZOO COUNTY, MICHIGAN

Amatun Noor, M.A.

Western Michigan University, 2006

Lead-based paint is the major source of childhood lead poisoning for children under six in the United States and was commonly used in pre-1950 homes. The main objective of this study for Kalamazoo County, Michigan is to identify risk homes to for public health workers, and determine common socioeconomic factors from the US Census that can be used to identify relative risk across census tracts. A Geographic Information System (GIS) is applied to locate the risk homes of 485 children provided at the aggregate level by the Michigan Department of Community Health. Independent variables were derived from the U.S. 2000 Census. A location quotient shows that the highest risk zone is mainly located within city limits. A multiple regression model at the census tract level verifies that old housing is the primary risk factors and that the children of African Americans and Hispanics estimated at the census tract level are more often exposed to this hazard than children of other ethnic groups in Kalamazoo County.

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CHAPTER I

INTRODUCTION

Applications of GIS and Spatial Analysis in Medical Geography

In many ways, it is difficult to differentiate between Geographic Information Systems (GIS) and spatial analysis as both are analytical perspectives that deal with similar aspects of geography as a spatial science. This has forced geographers to come up with an explicit meaning of spatial analysis that will distinguish this crucial approach from GIS. Spatial analysis is defined as "a general ability to manipulate spatial data into different forms and extract additional meaning as a result" (Bailey, 1994). For practical purposes, GIS is defined as: "a computer-based system to aid in the collection, maintenance, storage, analysis, output, and distribution of spatial data and information" (Ormsby et al., 2001). The use of GIS has become widespread during the past two decades. This spatial technology has become mandatory in many settings, and GIS is now an essential tool for business, government, education, and non-profit organizations. GIS have been used to fight crime, protect endangered species, reduce pollution, cope with natural disasters, analyze the AIDS epidemic, and to improve public health. In short, GIS has become an indispensable tool in addressing some of our most pressing societal problems throughout the world. Data representing geographic features can be visualized and analyzed as points, lines and polygon features in case of vector data.

On the other hand, spatial analysis deals with the use of statistical techniques in conjunction with a set of measurements or observations for one or more attributes taken at one or more specific locations. The purpose of all spatial statistical techniques is to build a model for the graphically depicted data and to assess the relative merits of different hypotheses concerning some arrangement or property of the data as this varies across locations. The difference between statistics and spatial analysis is that spatial analysis goes beyond fundamental statistical approaches in that location is a component of each analysis.

Geographers use spatial analysis within the context of the scientific method in at least two distinct ways. Explanatory methods of analysis are used to suggest hypotheses whereas confirmatory methods are used to help confirm hypotheses (Rogerson, 2001). Methods of visualization or spatial description lead to characteristic analysis of the spatial distribution of data. On the other hand, statistical methods could also confirm the pattern of spatial distribution of that very data. Geographers apply confirmatory methods for in-depth analysis of many types of spatial data. Descriptive statistical techniques are applied to explanatory methods of analysis whereas inferential statistical technique are used to infer something about the population of the sample based on a smaller sample and are more likely to lie within the class of confirmatory methods.

Momentum has steadily increased over the past centuries as researchers search for more and more knowledge about the causal factors in human illnesses. The analysis of causes of human illness and death has greatly influenced our methods of classifying health problems (Pyle, 1979). This paradigm of spatial analysis of both the causes and patterns of disease has given rise to a promising sub-discipline known as "medical geography". There has been interesting research conducted on the distribution and pattern of many diseases including infectious diseases (i.e. cholera, malaria) and chronic diseases (i.e. cancer, AIDS) on local, national and global scales.

Human disease has become part of an increasingly complex system given the rapid expansion in the spatial interactions of humans and environments in the contemporary global era. This has led to the dispersal of once localized and more specialized diseases often caused by local environmental hazards. For example airborne diseases such as asthma are now common place throughout the modern world.

In short, with the growing use of the chemicals and compounds that constitute the products of modern industrial society, we live in a world full of hazards that disrupt our daily life. Sometimes we are aware of the dangers that lie before us and sometimes they are not visible, or we do not have the knowledge to perceive the potential hazards. This behavior of human nature has made the management of environmental health risks more complex than ever. This enigmatic interaction of human beings and environment has led geographers to address the social, physical and economic problems caused by environmental pollution in both spatial and temporal contexts. In this world of expanding technology, people have become more conscious of their health which has brought health issues to the front page of our newspapers. In the past, geographers were largely interested in dealing with environmental components related to health problems, but now we are not only aware of health hazards, but wish to analyze the behavior that might be causing the environmental problems. In this thesis, I looked at a common environmental problem, lead poisoning of children found in Kalamazoo, Michigan. To study the problem, I have decided to use the spatial methods that are the hallmark of medical geography.

A Brief History of the City of Kalamazoo in Kalamazoo County

Kalamazoo County was officially organized in 1830. Its parent county is St. Joseph County and once the county was formed the county seat became what is now the City of Kalamazoo. This county was organized by an act of the Territorial Legislature and approved by the Governor on July 30, 1830. The town of Bronson, named after the founder of the village, was the county seat in 1831. This village was later renamed Kalamazoo by the legislative act in 1836. The county's name is derived from the word Kikalamazoo derived from a Native American language which means "the mirage of the reflecting river" in English. Modern Kalamazoo City, located in SW Michigan on the Kalamazoo River was established as a city in 1883. Over the next hundred years, the city became an important manufacturing center. Its many manufactures include paper and paper products, motor vehicle equipment, pharmaceuticals, musical instruments, plastics and chemicals. The many paper mills established between 1874 and 1918 really spurred the growth of this city while attracting numerous allied industries. Also the presence of general educational institutions including Western Michigan University (1903), Kalamazoo College (1833), Nazareth College (1924) and Kalamazoo Valley Community College also drew younger generations to the city. Figure 1.1 provides a graphical summary of the expansion of urban places in Kalamazoo County from 1832 to the present. The US Census Bureau (2000) estimated the population in Kalamazoo County was 238603 residence. The male population is 49.1 percent and the female population is 50.9 percent. In case of Kalamazoo City, out of 238,603 persons in the County the population is estimated to be 77,145 persons.

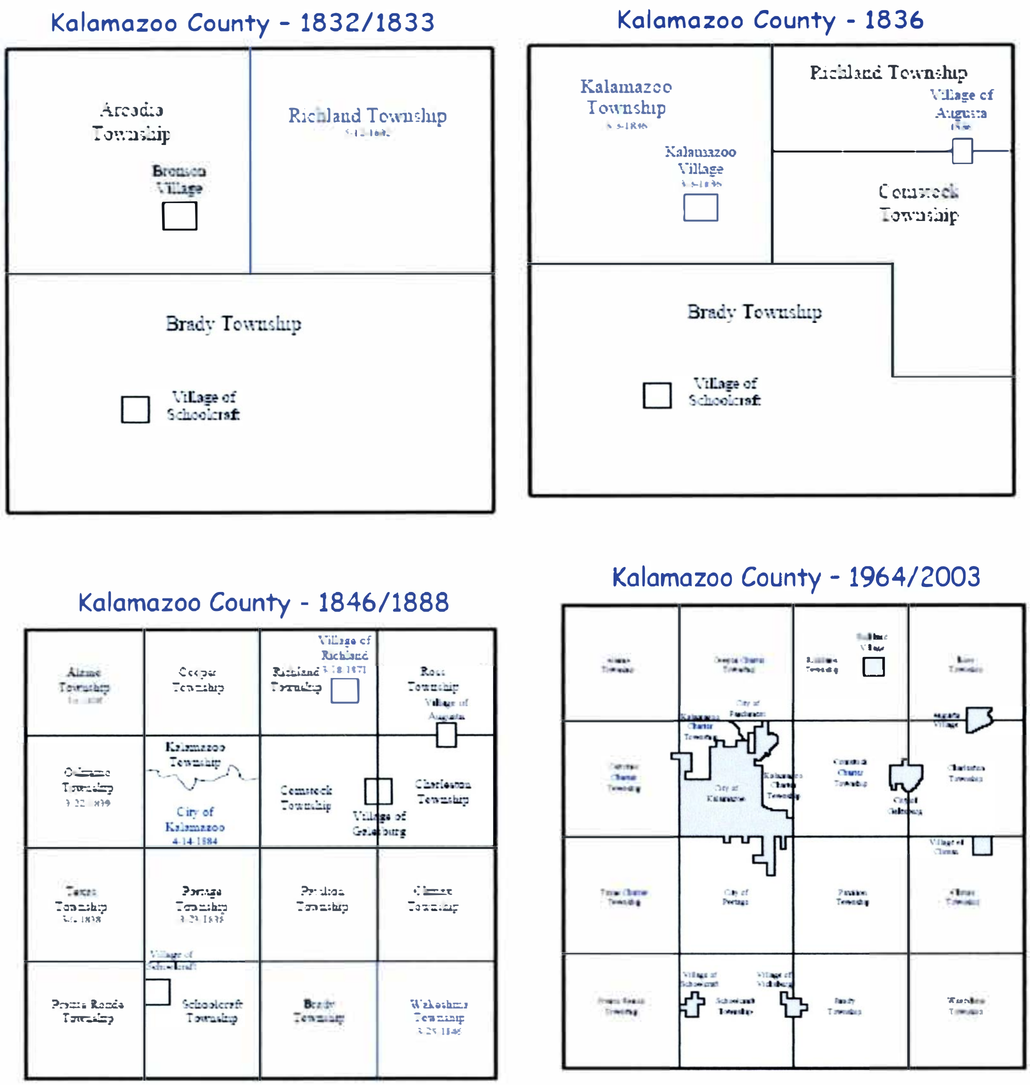


Figure 1.1: The growth of Kalamazoo County urban places
(Source: MIGenWeb/USGenWeb, 1998)

The long history of industry in Kalamazoo County and the concentration of people who arrived to work in these industries brought together two components of this research: people and lead. In the next section, I discuss the sources of lead that have continued to effect the people of Kalamazoo to the present.

Lead: An Element in the Environment

Lead is a transitional metal. Transitional metals are any of the metallic elements that have an unfinished inner electron shell that serves as transitional link between the most and the least electropositive in a series of elements. They are differentiated by multiple valences, colored compounds, and the ability to form stable complex ions. Lead is a bluish white metal, is very soft, and yet quite durable. This metal tarnishes upon being exposed to air. Lead has a wide range of uses and is used in many industries and products, especially those for plumbing and for other types of equipment exposed to water because it does not rust and is also very inexpensive (Stapleton, 1985).

Over time, lead has been used in many products including gasoline, batteries, pipes, and paints. However, over the course of the past fifty years, society has come to understand the great toxicity of lead, and the many medical problems that can arise from even slight exposure to lead. Regulations since the 1970s have limited the number of products that are now manufactured with lead. Still the extremely widespread use of lead in paints, solvents, polishes, pipes and many other daily products in earlier years means there is still an ample amount of lead. In the environment lead threatens human health in a number of ways.

Lead: A Silent Hazard

Hazards are best viewed as naturally occurring or human-induced processes, or events with the potential to create loss, that is, a general source of future danger (Smith, 1991). Lead can be considered as a point based environmental hazard occurring in a particular area causing human health problems. These problems are mainly for children under six years old, but there are exception that will be discussed later in the section.

Very severe lead exposure in children (blood lead levels > 80 μg/dl) can cause comas, convulsions, and even death. Much lower levels of lead poisoning still have adverse effects on the central nervous system, the kidneys and the entire hematopoietic system (blood and blood purifying organs) of children. Blood lead levels as low as 10 μg/dL (micrograms per deciliter) may not cause distinctive symptoms, but are associated with a decrease in measured intelligence and impaired neurobehavioural development (Davis et al., 1987). Many other health side-effects also begin at these low levels of concentration in lead poisoning cases, including decreased stature or growth, decreased hearing acuity (Schwartz et al., 1987) and a decreased ability to maintain a steady posture.

The US Centers for Disease Control and Prevention (CDC) in 1991 chose 10 μg/dl as an initial screening level for concern in tests for the presence of lead in children's blood. Still there remains considerable debate about the appropriate guidelines for elevated lead levels for infant children.

Current data on health risks and intervention options do not support generally lowering the criteria level, but federal lead poisoning prevention efforts can be improved by revising the guidelines for follow-up testing schedules for infants aged six years or less for children with blood lead levels of 5 μg/dl or higher (Bernard 2003).

Children who are exposed to lead for any significant period of time often exhibit behavioral problems. Needleman's (1979) study was among the first to raise public awareness about the effects of lead poisoning on children's psychological development. There is still much that is unknown in this area. Even small amounts of a common metal like lead have strong impacts on children's intelligence and their personality. Test scores associated with children exposed to lead support this fact. A study which broke students into two groups based on exposure showed the impact of lead on intelligence (Sciarillo et al., 1992). In comparison with a low level exposure control group, a group that had twice tested positive on two consecutive blood lead tests with lead levels in this bloodstream greater than or equal to 15 μg/dl had a significantly higher mean scores on the Total Behavior Problem Test.

Other researchers found a positive correlation between Toxocara Canis infection and lead exposures for New York City children as measured by the

Centers for Disease Control (Marmor et al., 1987). Toxocara Canis is associated with adverse neuropsychological effects which represents a threat to children's behavior.

Childhood Lead Poisoning: A Great Concern for Medical Geography

Currently lead poisoning of children under six years has become a great concern among public health researchers and personals. People cannot smell or taste lead but it is everywhere in water, food, soil, paint and other sources. It is an invisible hazard that can easily enter our children's bodies, slowly diminishing their intelligence and causing a range of behavioral problems. The geographer's main task with respect to the problem of lead poisoning in children is to identify the spatial distribution of lead in the study area, in this case, Kalamazoo County, and look for environmental, social and economic reasons for this spatial distribution. To examine the conditions that effect lead exposure levels and uptake in children, it is important to identify the health risk factors in the specific area included in the study. Previous research indicates there are a number of associated risk factors that serve as indicators for potential lead poisoning. Risk factors include the age of housing (pre-1950 houses contain lead on walls from lead paint), urban/rural status, race, socio-economic status, hygiene and nutritional status (Literature Review- Chapter II). The exploratory methods that identify these causes do not however, confirm how much impact these specific factors have on children who have elevated blood lead levels (above or equal 10 µg/dl defined by Center for Disease Control and Prevention). For this reason it is important to apply a regression analysis which will confirm the credibility of the risk factors of lead poisoning while also allowing us to rank these factors (independent variables) with respect to their relative utility as predictors of elevated blood lead levels. This confirmatory method is thus a very crucial technique to verify which social and environmental factors influence the level of lead poisoning in children under six years old. Once identified, those risk factors can be used to come up with a spatial pattern predicting future cases through the use of cluster analysis and to suggest priorities that should be used to treat existing cases.

Thus it can be said that spatial analysis and GIS potentially can play a vital role in deriving the causal factors while also identifying the spatial patterns of diseases that are the main concern of medical geographers.

Problem Statement

There have been public health reports by the Michigan Department of Community Health Department that deal with lead poisoning among children in Kalamazoo County. It is alarming to note that based on the U.S. census, 25 percent houses in this county are pre-1950 housing and that there are 18,597 children who are under 6 years old (MDCH, 2003) who may be exposed to this hazard. This has resulted in a large number of children with elevated blood lead levels mostly who are from low income families living in pre-1950s housing. Medicaid children are screened in Kalamazoo County. Results of this screening determined that 485 children had lead in their blood out of the 9,094 tested. This should be quite a great concern for this community. It is important to come up with a strategy that will prevent childhood lead poisoning in Kalamazoo. Public health researchers in Kalamazoo County can provide us with the tabular data of children who have elevated blood lead levels and the locations where these children live. Unfortunately they are unable to analyse the distribution of affected children in relation to the location of old housing, rental housing, and percentage of particular ethnic groups in a specific census tract. This spatial analysis that is the linkage between spatial and tabular data is made possible only by applying GIS.

There are a number of geographic research projects that deal with lead poisoning. It was interesting to find out that these researchers have applied GIS tools to analyse the risk factors and to predict the risk areas of those specific studies. One researcher used tabular data from blood lead screening, county tax assessors and the US census to predict statistically based lead exposure risk levels mapped at the individual tax parcel unit in six counties in North Carolina using GIS as the main decision tool (Miranda et al, 2002). Also it was interesting to note that a cohort population of Jefferson County, in

Kentucky, living in old housing are being analysed GIS to provide the Health Department data for decision making for childhood lead poisoning prevention activities (Reissman et al., 2001). Children who are at risk are identified by geocoding which will help the outreach workers to screen those most vulnerable (CDC, 2000). There was another research project which I found quite unique. A study done in Tijuana, in Mexico, took soil samples as the point sources to pinpoint the risk factors that were responsible for lead poisoning (Elisabeth, 2002).GIS was used to determine if there was any relationship between the contaminated soil sources and the elevated blood lead level in the children.

It is unfortunate that there has not been any GIS lead poisoning research done in Kalamazoo County. GIS research that was conducted in other states and other countries could be applied to our county which is in great need of spatial analysis of childhood lead poisoning. My study, the first of its kind, will target old housing as the main risk factor for this dreadful child hazard.

Objectives of the Study

1) Spatially locating the children who have elevated blood lead levels (≥ 10 µg /dl)

2) Creating a map with predictive risk zones in Kalamazoo County for later use by public health workers.

3) Determine the factors that are associated with the elevated blood lead levels (EBLL) among the children.

4) Analyse the demographic and housing characteristics in relation to EBLL children.

Expected Outcome

Most children with elevated blood lead levels live in old housing (Reissman et al., 2001) and come from low income families. Usually demographic studies of children with elevated levels of lead in their blood indicate that a majority of the children are from African American and Hispanic ethnic groups (CDC, 2000). I also hypothesized we might find that these at-risk children live in rental housing as they do not have the resources to purchase their own homes. They are more dependent on landlords for abating the lead in their homes. I expect elevated blood lead level children to be clustered mainly in the Kalamazoo City (versus Kalamazoo County) where housing is deteriorating.

CHAPTER II

LITERATURE REVIEW

Introduction

It is important for researchers to thoroughly analyse the problem at the heart of their studies in order to identify their objectives and develop a problem statement for their health research. Before I started my GIS and spatial statistical analysis for lead poisoning among children in Kalamazoo County, I went through a variety of different public health journals (i.e. *American Public Health Journal, Bulletin for the Center for Disease Control*) to understand the symptoms, causes and the consequences of this dreadful child hazard. Also it was important to pinpoint the main potential sources of lead in the environment for the Kalamazoo area. Environmental research related to childhood lead poisoning was provided by *Environmental Health Perspective* (Miranda et al., 2003) and the *Annals of the Association of American Geographer* (Griffith et al., 1998). It is essential to identify background information on the introduction of lead in environment and its toxicity so I can help to solve the problem of lead poisoning still facing many families in Kalamazoo County. In addition to research articles and reports, two Master's thesis in geography regarding lead prevention and poisoning were identified. The first was for

Providence, Rhode Island and the second was for Cincinnati, Ohio. The first assessed lead poisoning cases in Providence, Rhode Island (Plumer, 2000) and the second assessed lead hazard control in urban neighbourhoods of Cincinnati, Ohio (Ju, 2002). These studies provided the framework for my own lead poisoning in Kalamazoo County, Michigan.

In the following sections, I introduced issues related to the problem of elevated blood levels among children in Kalamazoo in a systematic fashion with a focus on old housing. I discuss lead testing the sources of lead found in the environment, the particular impacts of lead on developing children, mitigation efforts and treatment, the geographic distribution of lead poisoning among children in the US, and the potential benefits that can be derived through the analysis of the problem using GIS and spatial analysis.

Lead Testing

At the outset, it is important to know how lead levels are evaluated to determine if children are at risk. The CDC has determined that children who have tested lead levels of 10 μg/dl, or above, are at risk and are classified as elevated blood lead level children.

Lead testing of children can be completed in two ways:

(1) venipuncture: a process where the blood is taken from accessible veins through the use of a hypodermic needle.

(2) capillary testing where the blood sample is taken by a fingerstick using a small glass tube.

Usually venipuncture is conducted only for high-risk children as it is more invasive and capillary samples are taken for low-risk children. Venipuncture remains the least expensive strategy (Glotzer et al. 1994) because in the case of capillary testing, the health department officials or primary care providers doing the testing often have to proceed to venous testing methods for confirmation of high lead levels, if initially inflated levels are identified. This adds an extra step. Once medical professionals have identified those children exhibiting inflated lead levels who are affected by this lead, health officials need to verify the main sources that are causing this harmful problem to the children of our society. The next section will introduce common sources of lead in the environment.

Sources of Lead

Gasoline

Lead is an octane enhancer that increases the combustibility of fuel and was traditionally added to gasoline throughout the world until legislation in the 1970s stopped this practice. At that time, lead was found to be extremely damaging to public health, especially to the intellectual development of children, even at levels previously considered safe (World Bank, 2000). The issues related to lead poisoning are global and local. Leaded gasoline is one source not found anymore in the United States. Still the extensive use of two stroke engines in South Asian countries like Bangladesh in vehicles that serve as one of the main types of vehicles for public transports in cities besides rickshaws means that poisoning from leaded gas is still a problem in many parts of the world. Lower cost and mechanical simplicity make these two stroke engines that used leaded gas more popular than four stroke engines. These so-called "baby-taxis" are an indispensable transport mode in the cities of Bangladesh. Burning this type of gas was hazardous to the passers-by, passengers and the drivers. Bangladesh Petroleum Corporation, the sole supplier of gasoline in the country, removed lead additives from gasoline in July 1999 (ESMAP, 2002). Due to these environmental concerns, two stroke baby-taxis were successfully converted to CNG in late May 2000 by the Department of Environment. It can be said that gasoline lead reductions appear to be a major factor in the decreases in population lead exposure that have now been observed in many countries worldwide (Thomas et al., 2000). Industry is also a threat for lead poisoning in many countries of the world.

Industry

A study of 28 construction workers tested for lead in the workplace and reported to the California Occupational Lead Registry during March of 1989 showed 11 (39%) had blood lead levels of 60 μg/dl or greater (Maizlish et al., 1992). Many of these workers had not been warned of possible lead exposure and did not even know they were at risk. Despite the standards of the occupational safety and health administration, lead exposure in California adults remains a significant public and occupational health concern (American Journal Public Health, 1993)

In a study using testing pregnant women living near a smelting plant in Sweden, blood lead levels were analyzed during pregnancies for women living near the smelting plants and those who were shifted away from the plants to control areas. The research showed that an increase in blood lead level was found during pregnancy, despite increased blood volume and unchanged or decreasing environmental lead levels. This might be due to the mobilization of bone during pregnancy, which might have caused the increase in lead levels of pregnant women living in control areas (Lagerkvist et al., 1996). An optimistic study indicates that calcium intake may provide some protection not only at levels near the recommended dietary allowance but well above it (Hertz-Picciotto et al., 2000).

Housing

Drinking Water

Water may also be a source of lead contamination especially among children (Bois et al., 1989). An EPA report noted that twenty percent of lead poisoning occurs through the consumption of drinking water. Lead poisoning via drinking water can occur due to water flowing through lead pipes or through pipes using lead based solder (CDC, 2004). At times, chemicals that are used to treat the water also contain this hazard. However, lead in water may also occur naturally. In one study, after eliminating paint, furniture, food, yard soil, and toys as possible sources of the lead exposure to a family and children, public health officials discovered that the family's tap water contained up to 390 ppb lead and was being contaminated by lead solder used in the plumbing system throughout the newly constructed home (Stapleton, 1994).

Measures taken during the late 1980s and early 1990s have greatly reduced exposure of the general public to lead in most tap water. These measures include actions taken under the requirements of the 1986 and 1996 amendments to the Safe Drinking Water Act of 1972. But lead still can be found in some metal water taps, interior water pipes, or from the pipes connecting a house to the main water line in the street (CDC, 2000). Lead found in tap water usually comes from the corrosion of these older fixtures or from the breakdown of solder that is used to connect water pipes throughout the system. When water sits in leaded pipes for several hours, lead can easily leach into the water supply. It is the tendency for the metallic lead to leach into the flowing water that creates this problem.

Lead-based Paint

Focusing on lead paint and leaded gasoline, Warren in 2000, distinguished three primary modes of exposure -occupational, pediatric, and environmental. Taking lead out of petrol has dealt with only one source of exposure. The most serious hazards arise from old leaded paint in our homes, schools and workplace (Millstone, 1997). Lead can be found in high concentrations in three media to which children may be directly or indirectly exposed, paint, interior dust, and exterior soil or dust (CDC, 2002). Home repair and improvement industries including re-painting and renovation firms should all integrate lead safety into standard practices and further, address the reality of lead-based paint in older housing (Ryan, 2001). But these have not always been taken and problems remain rife, especially in lower quality housing such as rental apartments in inner cities.

Old housing that was built before 1950, typically was painted with lead based paint that contained up to 50 percent lead by weight. This is the "soul" of the problem. Currently children in 26 million households in the United States live in older housing stock and are potentially at risk (Reissman et al, 2001). In 1973, the Consumer Product Safety Commission established a maximum lead content in paint of 0.5 percent by weight, and in 1978 this amount was further reduced to .06 percent (Dignam, 2004) but, problems remain as leaded paint was used for so many years.

Other Contaminant Vectors: Soil and Dust

Soil and dust also may act as pathways to children's cases of lead poisoning. Lead can be present in the soil as small particles resulting for the breakdown of lead-based paint or come from gasoline and industrial sources as previously noted. The long term efficacy and cost-effectiveness of different measures to reduce lead levels in soil need to be evaluated. Reduction of dust lead is also important both as part of the de-leading process and as a means of interim risk reduction.

Children: The Most Vulnerable Group

Children between the ages 1 and 6 years are the main victims of lead poisoning. Whether the old house is in a large city, a small city or even a town, or village and whether the paint on the walls is ten years old or thirty years old, the two important factors are the presence lead-based paint that is peeling or can be picked off, and the presence of a small child who can get to the paint without supervision (U.S. Department of Health Education and Welfare 1974). A toddler does not have the sense to understand what is good or bad for her/his health. Some children in the crawling and early walking stage display behaviors known as "pica", or a desire to eat non-food substances. It is too much to expect for even a stay-at-home mother to watch her child all of the time. This pica behavior is not a disease but a tendency to experiment with materials using the mouth which might lead inadvertently to diseases or illness. Children have the tendency to put almost anything they can pick up in their mouths. Unfortunately, paint chips have a slightly sweet taste, making them more attractive to children than some other substances that might be found. The inability to watch small children all the time and their possible inclination to eat non-food substances are behavioral factors that contribute to this lead poisoning disease. It is reasonable to say that even if all of the babysitters and mothers knew about the dangers of eating paint chips and did a good job of supervision, they still would less likely be able to prevent children from eating paint, if paint was available. So the health officials working in this field emphasize the identification of vulnerable children who are living in at-risk houses that have this lead paint. This is an important issue.

Central to this research, and to the role of geographic research related to medical geography, is the fact that the best and easiest way of preventing lead poisoning is to mitigate risk by identifying and treating lead painted walls in older homes and especially older rental homes.

Figure 2.1 shows that African American children are more vulnerable to lead poisoning than white children in United States because African American families statistically tend to live in older, thus more at risk, housing. For young children aged 6 months- 5 years, blood lead levels among black children are, on the average, 6 µg/dl higher than among white children (National Center for Health Statistics, 1982).

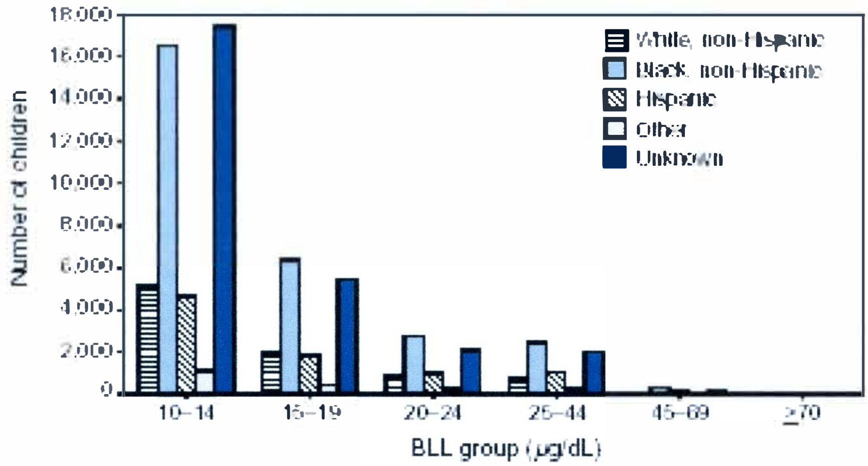


Figure 2.1 : Number of children with confirmed blood lead levels by racial group and program relevant BLL group – selected US States, 2001(Source: CDC 2003)

Among all children, the next question is to determine which are most susceptible to lead poisoning. Usually it is observed that children who are unhealthy and have poor diets are more vulnerable to lead poisoning.

Nutrition

Iron deficiency is the most common nutritional problem among children worldwide, and lead toxicity is the most common environmental health threat to children. Both iron deficiency and lead poisoning disproportionately affect children younger than 5 years old, those of lower socioeconomic status, and those living in inner cities (Wright et al., 1999). Also it is interesting to note that iron deficiencies are associated with low socioeconomic status and found in high proportions among Southeast Asian and Hispanic population. (Sargent et al., 1996)

Poor Housing Quality

Poor housing is a major risk factor associated with health risks for children under six years. High risk areas for lead poisoning are almost synonymous with slums, where old deteriorating housing exists. In these poor quality areas, accessibility to flaking paint and broken plaster, joins with a high incidence of pica due to a lack of adequate parental supervision provide an optimum environment for lead poisoning cases among children.

Mitigation Efforts

A crucial goal for risk management related to lead poisoning is to remove all lead paint from all housing in the United States and the world. It would be prohibitively expensive to meet this goal in the immediate future.

Short term goals of partial removal help, but tend to postpone efforts for complete removal. An important first step is to identify all houses that potentially put their residents at risk. The most common intervention strategy is employing a one-time treatment (improving environment, changing behavior, attitude and knowledge) that showed statistically significant reductions in child elevated lead levels (Saegert et al., 2003). One effective way of mitigating this hazardous substance is by abatement.

Abatement

The most important step is actually abating all lead hazards. This may involve many activities such as corrosion control to reduce the amount of lead in drinking water or covering or removing lead-contaminated play coils in parks and playgrounds. In many cases, the primary risk will be lead-based paint and the primary form of risk reduction will be preventive de-leading abatement that occurs before children have been poisoned (CDC 1991). According to Michigan's Lead Laws (MCL 333.5451-5477) abatement means "an activity designed to permanently eliminate lead paint hazards."

In a *New York Times* (July 1, 2001) article, Neil Genzlinger criticized that despite the presence of a long-term ban on the use of lead-based paint, the deadly problem of lead still remains in the state of New Jersey. Genzlinger argues that "lead abatement is a medical issue, a political issue and, above all, a money issue" which further complicates the mitigation of the threat.

Maintaining a "Lead Safe Home" (HUD, 1997) should be required reading providing remediation strategies for all those interested in maintaining healthy homes for themselves and their children, be they parents, property managers, community housing organizations, or public health officials (Millstone 1998). In the HUD booklet, Livingston provides a step-by-step guide detailing simple, effective, low cost lead poisoning prevention based remediation strategies (HUD, 1997).

Abatement, then, is a preventive method that can check lead poisoning whereas children who already are at risk need to be treated as quickly as possible through chelation therapy.

Chelation

The single most important factor in managing childhood lead poisoning is reducing the child's exposure to lead. Once children are poisoned severely, chelation therapy could be applied to get rid of lead from the blood of a child. Within a few days, however equilibration among organs takes place and may result in a rebound; thus the blood lead level must be rechecked seven to twenty-one days after treatment to determine whether retreatment is necessary (Piomelli et al., 1984). Beyond the emotional dimension, chelation can be very expensive and represents a significant health risk in and of itself.

Before this problem gets out of hand, it is important to have a preventive strategy to ensure the health of the children of each county. For this purpose it is essential for the health providers to act accordingly.

Risk Management: The Role of Health Providers

Pediatric health-care providers working as part of the public health system, must play a critical role in the prevention and management of childhood lead poisoning (CDC, 1991). Their roles include:

- Educating parents about the key causes of childhood lead poisoning
- Screening children and interpreting blood test results
- Working with appropriate groups in the public and private sectors to make sure that poisoned children receive appropriate medical, environmental and social service follow up
- Coordinating with public health officials and others involved in lead-poisoning prevention activities.

Along with educating parents about nutrition and developmental stages whenever possible, health care providers should discuss the potential hazards of lead. They should focus on the major likely preventable sources of high dose lead poisoning in their communities. Parents should be told of the potential dangers of peeling lead-based paint, the potential hazards of renovating older homes, and the need for good work practices if occupations or hobbies include exposure to lead. In some communities, parents should be warned about the potential for lead exposure from improperly fired ceramic ware and imported pottery. In others, where lead levels in drinking water are a concern, parents should be advised to use only fully flushed water (that is water that has not been standing in pipes for a prolonged time). Pipes with lead solders or lead pipes should be removed as quickly as possible.

Geographical Dimensions of Home-based Lead Hazards

Lead is a Problem on a Global Scale

Lead poisoning of children is a global health issue. It is one of the common health issues where both developed and developing countries are impacted. Although the sources of lead differ from place to place, the "after effects" remain the same. For example in Latin America, poorly glazed pottery used for food consumption can cause high lead levels (CDC, 2002). In the case of Bangladesh, the Centers for Disease Control and Prevention evaluated children at five primary schools in Dhaka, the capital city of Bangladesh, to determine blood lead levels (BLLs), the sources of environmental exposure, and the potential risk factors for lead poisoning. Findings showed that elevated BLLs correlated with soil eating (geophagy) and low parental educations as well as for children living in homes in close proximity to major roads (Reinhard et al., 2001). BLLs measured were similar to those in other countries of the world that use leaded gasoline. No other potential sources of lead exposure were consistently identified in the study, so the combustion of leaded gasoline is the main source of lead exposure in Dhaka, resulting in hazardous contamination of the environment. This is in contrast to the situation in Kalamazoo, Michigan when the number one source of pollution is lead-based paint (MDCH, 2000).

Lead Remains a Problem on the National Scale

Childhood lead poisoning remains an important health problem - particularly among the urban poor of United States, but before 1970, the problem was worse. Thousands of children annually suffered major brain damage from lead encephalopathy. Child mortality was high. In Boston, between 1949 and 1954, many children displayed symptoms of lead poisoning; some of these children became ill, and some died as a result (Schoen, 1999). Lead exposure is also linked to differential patterns of urbanization and industrial activity and it is certain that lead abatement policies can reduce lead exposure (Bailey et al., 1998). From Figure 2.2, it is evident that in 2001 States located in Midwest and Northern region of US have high percentages of EBLL due to old housing stocks in urban areas.

BLLs in urban children in the past were high by current standards: according to the National Research Council, the research arm of the National Academy of Sciences; the National Academy of Engineering and the Institute of Medicine. Symptomatic childhood lead poisoning was associated with a mean BLL level of 178 µg/dl, and fatal lead encephalopathy was associated with a mean BLL level >300 µg/dl. A child's life is out of immediate danger if the BLL level is <100 µg/dl and the CDC officially defined the lower threshold for lead poisoning at 60 µg/dl. At present, however, the United States has lowered risk lead level to 10 µg/dl.

It is still depressing to note that in the not so distant past, most of the children who lived in urban communities—where the prevalence for elevated blood lead levels among children was 12 times higher than the national prevalence—were not tested for lead poisoning (Dignam, 2004). So there is no way of knowing how prevalent these problems actually were in the past or the devastating effects of lead on US children overtime.

Chicago children, mainly African American children, and found that 8% of these children had BLL >50 µg/dL. Although only 8.9% of children at high risk for lead poisoning had symptoms of the disease, lead poisoning still was a health threat to these children and often necessitated chelation therapy for decreasing the body lead burden. These emergency measures were

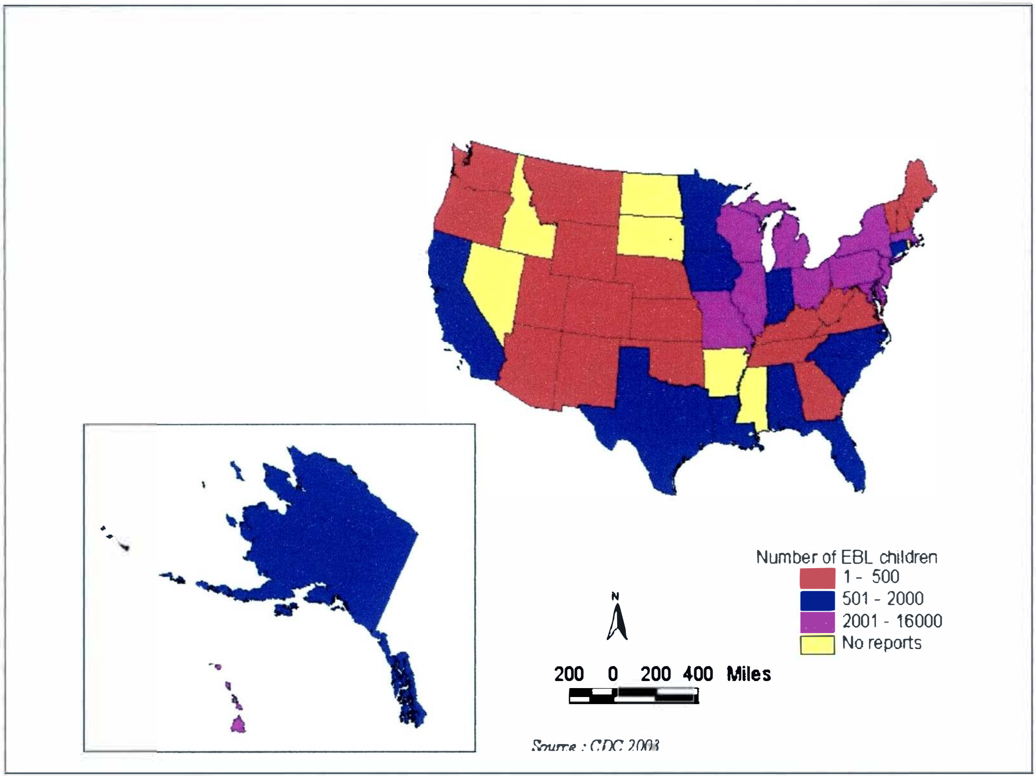


Figure 2.2: Spatial distribution of elevated lead levels in United States, 2001

followed up with diagnostic studies that resulted in a better understanding of lead poisoning.

Throughout the US, lead-based paint was commonly used for homes built before 1950. The percentage of lead used in paint gradually dropped between 1950 and 1978 and lead-based paint was banned altogether in 1978 as a consequence, the mean and peak blood lead levels for city children decreased over a nine-year study period from 1972 to 1981 in Newark, New Jersey, signaling a lessening of disease severity. But the increase in numbers and rates indicates that childhood lead poisoning still exists as an environmental and social problem (Schneider et al., 1986). It can be said that repeated redefinitions of lead poisoning levels are linked to changing attitudes toward health, safety, and risk (Warren, 2001).

As housing stocks get replaced, some locations report reductions in lead poisoning. The number of existing U.S. housing units built before 1950, when paint had high lead content, decreased from 27.5 million in 1990 to 25.8 million in 2000; however, pre-1950 housing units are located in all states ranging from 12,472 in Alaska to3,309,770 in New York. However, in 2000, approximately 80% of the 25.8 million pre-1950 housing units in the United States were concentrated in only 21 states, and approximately 50% were located in seven states (California, Illinois, Massachusetts, Michigan, New York, Ohio, and Pennsylvania). Figure 2.3 shows the relationship of pre-1950 housing units and children with confirmed elevated lead levels in 2001. This indicates that old housing is the major risk factor in United States that is causing childhood lead poisoning. Only the state of Illinois is exceptional which indicates that other risk factors are causing the deterioration of child health in that particular state.

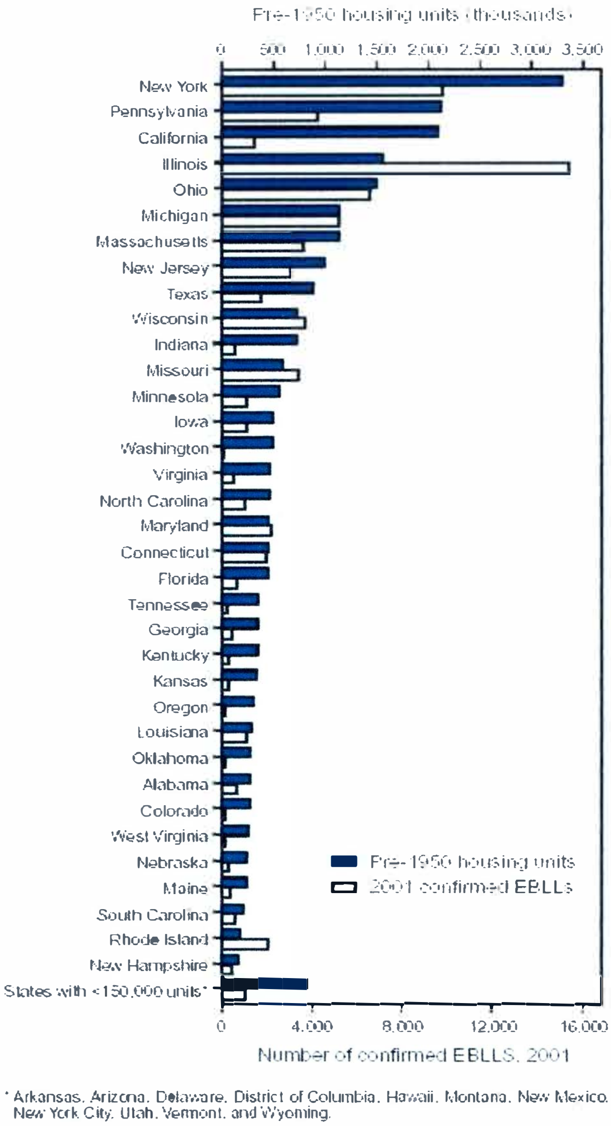


Figure 2.3: Relationship between pre-1950 housing and number of 2001 confirmed EBLLs (Source: CDC 2003)

Lead Poisoning at the Local Level

The *Detroit Free Press* examined the nature and extent of lead contamination in southeastern Michigan. The series focused on the potential threats posed to children's health and stunted cognitive development due to the ingestion of lead paint and lead paint dust in residential neighborhoods, and the broad dispersal of lead-laden soils from historical airborne deposition of leaded fuel emissions. The study also identified specific manufacturing facilities known to represent risks in the communities. Since 1972, a federally funded lead screening program has been operational in Detroit, Michigan. Higher blood lead levels were associated with lower education at test scores, lower incomes, and an increased proportion of single parent families (Talbott et al., 1982).

In Figure 2.4, it is evident Southwest Michigan has higher percentage of childhood lead poisoning than other parts of the State. Lower proportion of this dreadful hazard is observed in Upper Peninsula. My study area - Kalamazoo County seems to be in a danger zone as the percentage of lead poisoning seems to be quite high (percent ranging from 1.4 - 2.5).

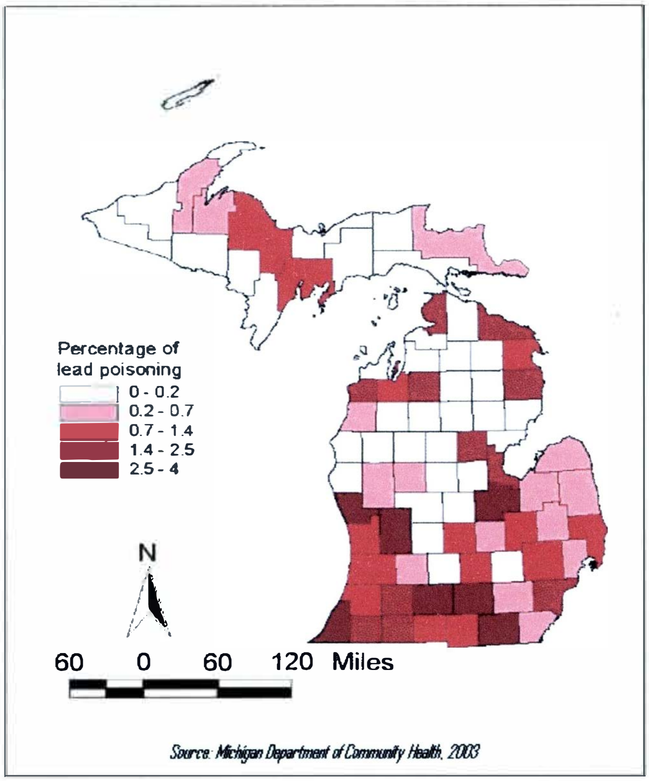


Figure 2.4: Spatial Distribution of Childhood Lead Poisoning in Michigan State, 2003

Recommendations for Reductions of Lead Poisoning

A Michigan state task force (Kalamazoo Gazette, 2004) made a number of recommendations to reduce instances of lead poisoning in children including:

- Setting up a public health trust fund to provide a stable source of funding for lead poisoning control, prevention and remediation.
- Developing a mandatory registry to list pre-1978 rental properties, where buildings constructed after 1978 could be voluntarily listed.

- Creating a public awareness campaign to make sure parents understand the dangers of lead exposure and are encouraged to seek lead testing of children at appropriate intervals.
- Setting up a commission to evaluate and coordinate lead resources and activities.
- Expanding the remediation and control of lead hazards in residential areas.

Now the crucial task of the researchers is to find out if these recommendations will lead to an improved environment where our children can be free of this domestic hazard. It is important to note that even if the risk houses with lead-based paint are identified and the housing authorities notified and the parents are educated regarding lead poisoning, outreach workers cannot force them to control the lead hazards in those risk areas. It is something that has to come from individual consciousness if the parents want their children to have a better and healthy life. The choice is up to the parents, landlords and community leaders to make an environment risk free from this slow poisoning hazard.

<u>GIS Application for Lead Pollution Remediation</u>

GIS in this modern technological era has become an indispensable decision-making tool for different aspects of geographical research. Several recent studies have used this essential geographic information system (GIS) tool to compare the spatial distribution of blood lead levels with identified risk factors for lead exposures of children (Guthie et al., 1992; Reissman et al., 2001; Miranda et al., 2002). The studies were implemented at the census tract, block group, block, and/or U.S. Postal Service ZIP code level of resolution and build upon previous work that developed guidelines for using GIS technology in environmental epidemiology research and lead exposure analysis. This research will also use census data to evaluate lead poisoning cases in Kalamazoo County. The following chapter will disuss the census tract data that are used in conjunction with the home addresses where lead was found to be a problem to create a predictive model linking homes with lead poisoning cases reported over the past decade with socio-economic variables (mean values) at the census tract level.

CHAPTER III

METHODOLOGY

Lead poisoning has become a great concern for the children of this generation. Children under 6 years are more susceptible to lead poisoning due to pica behaviour, and absorption of lead from the gastrointestinal tract is higher than for adults. Again, young children with their developing nervous system are more vulnerable to this hazardous lead. As has been mentioned in earlier chapters, lead poisoning has multi-facet sources but, in case of the most vulnerable group, this study pinpoints the old housing stock that was painted with lead-based paint as the main source. In 1950, the paint in houses was identified as one of the major sources of lead poisoning and the lead-based paint was banned by the Consumer Index Act of 1978. The CDC has identified old housing (before 1950) to be the potential leading source of lead poisoning. This finding helped to guide my decision regarding this research, concentrating on these deteriorated houses. Specifically, this research focuses on locating the houses where children with elevated blood levels have lived in the past decade in Kalamazoo County. This study also seeks to examine the relationship between several socio-economic factors at the census tract level that might be associated with homes where lead paint is still a problem. Finally, based on conclusions from the findings, the predictive risk zones in Kalamazoo County for public health workers will be defined. For this purpose, the GIS analytical method, incorporating spatial analysis techniques and several sets of data are vital tools for the project. Methods, techniques and required data sets and their sources are described below sequentially.

Locating Vulnerable Children and At-risk Houses

While working as an intern at the Kalamazoo County Health & Community Services, I was asked to extract the secondary data of the children who have been tested for lead poisoning from the STELLAR database. Working as an intern, the data set that had the addresses of tested and EBLL children was geocoded (address matching procedure) for locating the at-risk houses in Kalamazoo County. Also it was possible to identify the multiple houses which were defined as individual risk houses having more than one child resident having lead poisoning. Once my internship was completed and after Health Insurance Portability and Accountability Act (HIPAA) training, I was allowed to use two derived variables – The aggregate number of homes with lead poisoning cases at the census tract level for use in my thesis. By querying the field of lead results in a geocoded shapefile layer, I was able to verify which tracts had higher range of level of lead poisoning of children as compared to all other tracts.

Background on the STELLAR Database

The data for children with elevated levels of lead in their blood is collected from the Michigan Department of Community Health which was in a STELLAR database. STELLAR is a customized database format used by community health workers to keep health records for at-risk children. STELLAR (Systematic Tracking of Elevated Lead Levels and Remediation) was designed to replace paper-based systems for tracking and managing Lead Mitigation and Lead Risk Programs. It lets the professional health worker enter the blood lead test results or transfer them electronically into their system. The main purposes of the STELLAR database are to track the following activities (STELLAR 3 User's Guide, 1999)

- Screening of children for lead toxicity
- Identification and confirmation of cases
- Medical management of cases
- Investigation and abatement of lead hazards, primarily from leaded-paint, in the home environment of cases.

While only aggregate derived data was used in this thesis, typically the STELLAR database contains the following information:

Address Information

Lead Program information – such as children's names and addresses, lab reports, and provider information – is stored and tracked in this database. It provides addresses of the children who are tested for lead poisoning. If a child's address changes, STELLAR can record the new address as well as the old. In addition, it can store supplemental addresses for a child due to alternative housing or guardianship changes. Due to the fact that blood lead level problems are linked to addresses, STELLAR can store and track multiple addresses per child, as well as the dates of occupancy in any given home. Again, only the location of homes and results of tests were used in this thesis. No other personal data was used in the analysis.

Child Information

Most of the children's records stored in Stellar are entered from the Blood Tests data entry window or imported from another program called Lab Import. Name, date of birth, sex, ethnicity, and race are mainly recorded in this data file. The following variables are included in each child's record:

Blood Test Record

Blood test record is the most essential information provided by the STELLAR database. Date sample, sample type (capillary, venous, unknown), and lead result are the major records that are input by the health workers for the database.

Home address data for all screened children was and the aggregate data at the census tract level was joined to the spatial data (maps) for Kalamazoo County. The address data of homes with elevated blood lead level children can be geocoded to locate the old houses that are at risk for the next generation of children of Kalamazoo County. While looking at the Kalamazoo County Health and Community Services, I had to query the database for homes with children who had lead poisoning above 0 μg/dl. Data were then exported as a .dbf file. I applied the same procedure for children who had lead levels equal or above 10 μg/dl (EBLL defined by CDC). The data aggregated to the census tract level was used fir the research with permission from Dr. Annie Wendt of the Kalamazoo County Health and Community Services.

Geocoding

For this research, the health data was geocoded by taking the zipcode of each tested child's home address as an address locator and matching the homes of children who had elevated blood lead levels of children in Kalamazoo County. I used ESRI ArcGIS for the project. The spatial data was collected from the Michigan Center for Geographic Information library which has shapefiles for transportation (street, highways), Tract, City of Kalamazoo and County boundary. The homes of children with elevated blood lead levels are indicated as point features. These features are located within the county census tracts. Mapping these residences will provide a better spatial analysis of the data.

The first step of the geocoding process is to create a "geocoding service". Geocoding services have different styles, each appropriate to reference data with different attributes. For this case I applied the "US Streets with zone" style that is used with street reference data that contains a street name attribute and beginning and ending address ranges for each side of a street.Ususally the "US Streets with Zone" style comes in two versions: (File) for reference data in shapefile format and (GDB) for geodatabase format. The Kalamazoo Street layer is a shapefile. I applied the file format. In the input address fields frame, it is important to specify the fields from address table (addresses of elevated blood lead level children) that contain address information. STR_ADDR field is selected for the street address information and ZIP_CODE for selected for the zone information to locate homes where children who have been tested for lead poisoning live (or have lived) over the past ten years. This lead poisoning geocoding service is created in ArcGIS. The next step was to add this geocoding service to ArcMap in order to geocode. The main objective of geocoding is to create a table of addresses (homes). It is essential for ArcGIS to standardize the addresses in the address table for the geocoding which is done by the geocoding services. Every address is divided into four components: the street number (i.e., 221), the street name (i.e., Maple), the street type (i.e., St), and a suffix (i.e., W). The Kalamazoo Street shapefile is already standardized – each address part is a separate attribute. ArcGIS, then, generates a list of probable or possible matching location for each address for the file I called final_elev_chd.dbf table (these are the addresses of tested children).

For ArcGIS to make a match and create a point feature, as a specific home matching score must reach a certain level so that it can match the address. By default the minimum match score is 60. There were 485 cases of homes that had a resident in the past ten years with a positive lead test (we do not have individual data). Initially, it was possible to locate 60 percent of the 485 homes in Kalamazoo. Then, through a GIS process called interactive address error mapping, an additional 25 percent of homes were located on the map. Ultimately, 85% of all homes were located using the GIS.

Identification of the Predictive Risk Zones in Kalamazoo County for Public Health Workers

In order to develop the predictive risk zones for childhood lead poisoning a location quotient was used. A location quotient indicates the ratio of homes with children who have elevated blood lead level in a specific census tract to all of the children who live in that particular tract based on data from the 2000 U.S. Census.

The following location quotient equation will be used:

X = (No. of EBLL in X tract / Total EBLL in the county)

X is extracted from the attribute table of the geocoding layer by identifying lead cases in specific tracts and dividing the values by the total lead cases in Kalamazoo County

Y = (The estimated number of children in X tract / Total population of children in the county as estimated by 2000 U.S. Census data)

Where Y is calculated from the population information for each tract found in the tract layer and dividing this value by the total population of this county.

LQ = X / Y

It should be noted that Tract 4.02 (number of EBLL = 1), Tract 8.01 (11) and Tract 8.02 (1), Tract 7 (0), Tract 30.01 (0) and Tract 20.01 (0) are missing from the location quotient table in Appendix A.

The LQ are calculated on the basis of the tracts provided by the US Census Bureau whereas the number of children with elevated lead levels in their blood is extracted from the attribute data of the intersect layer of geocoding and tract layers (provided by *MCGI*). This resulted the program identifying 472 children with lead poisoning instead of the 485 cases in Kalamazoo County found in the STELLAR database.

If the LQ is greater than 1, then homes with children with elevated blood lead levels are over represented in any specific tract. In this case, it can be said that in tract 3, the number of homes with children with elevated blood lead levels are above the expected number due to chance. These areas are shown in the map in Chapter 4 (results) as high risk zones. This could be due to a high percentage of older housing. If the value is below 1 then lead poisoning is under represented which can be shown in the map as lower risk zones. The tracts that do not have a high proportion of homes with children with lead poisoning can be shown as no risk zones. Finally a risk map was generated that will be used by Kalamazoo County Health Community Services to identify areas that need particular attention.

Before superimposing this geocoding layer on the demographic and housing layers it is important to verify the major risk factors that are responsible for this childhood lead poisoning in the city as well as in other places throughout the world.

<u>Determining Factors Related to Lead Poisoning</u>

Data Sources and Variables

To find out the main causes of lead poisoning in Kalamazoo County, it is important to identify the most significant risk factors. For this purpose socio-economic data was taken from the US Census 2000. All variables were collected at the Census tract level.

Based on my review of the literature, the probable risk factors associated with lead poisoning at the census tract level that I chose to incorporate in my study include:

- The percentage of children under 6 years
- The average family size
- The ethnic composition of the census tract (percent of African American, Hispanic)
- The prevalence of old housing (percentage of housing built before 1950)
- Homeownership (percent of renters)
- Family household types (percent of single mothers)
- Population below poverty level (percent of poor population)
- The quality of the housing (percent of lack of plumbing facilities)

In general, the greater the number of homes with children concentrated in a specific tract, the greater the possibility of having homes where children with a higher percentage of EBLL may live. From the same point of view, family size could also play a vital role because the greater the number of children in at- risk houses, the greater the chance that some of these children will have elevated blood lead levels. There have been a number of studies that found out that African American or Hispanic populations were more vulnerable to lead poisoning (CDC, 2003). It could be that race correlated in some cases with poor housing quality and nutritional deficiencies of those children as well as lower education levels of the mothers which might be an additional reason for a large number of children at risk. Also, it is important to know that if single motherhood is associated with elevated blood lead level children as it may be difficult for single parents to look after their children by themselves.

The literature suggests that old housing units that are built before 1950 are identified as the major risk houses due to the widespread use of lead in paint for homes built at that time. Therefore I took the percentage of old housing units before 1949 and 1939 from the census data as surrogate variables. These old housing units are generally rental housing units. Therefore I decided to also use the percentage of rental housing of total housing units to find out if any relationship exists with this variable and the percentage of children with elevated blood lead levels. Usually people who tend to live in deteriorated old housing cannot afford to live in better quality housing. Therefore, at the census tract level, it can be assumed that the families living in these areas face poor economic conditions and low incomes. Hence, the percentage of the population living below the poverty level was also used as another census variable in the regression model. My research would become subjective if I did not consider other risk factors besides lead paint. There is a substantial evidence to prove the relation that exists between lead-based paint dust intake of children and the presence of high levels of lead in children's blood and I considered a lack of plumbing facilities (census variable) to verify if water quality had any kind of impact on childhood lead poisoning.

To summarize, housing characteristics taken from the U.S. Census for each census tract (i.e. household size, old housing) and socio-economic characteristics (i.e. mean income level, mean educational characteristics of the mothers) for Kalamazoo County can be taken as independent variables that determine the factors responsible for variable levels of lead poisoning in children by census tract. Using these data, a logistic regression model was run to verify the main risk factors that are responsible for this dreadful hazard. SPSS software was used to generate the models. Again, all data for the regression analysis was acquired from the U.S. Census.

Multiple Regression

Multiple regression analysis is concerned with the dependence of one variable on a set of independent variables (Appendix B).

The typical multiple linear regression equation is written as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_1 X_2 \ldots\ldots\ldots\ldots + \beta_k X_k + e_i$$

Where β_0 is the intercept term

β_1, β_2, β_k are the regression coefficients

X_1, X_2, X_3 are the independent variables

e_i are the residuals of the model

Again, in this research the independent variables from the U.S. Census include the percentage of children under 6 years, the average family size, the percentage of old housing built before 1940, homeownership, the percentage of homes reported as single parent homes, the percent of population living below the poverty level and the percentage of rental housing. The dependent variable is the percent of children with elevated blood lead levels by census tract for Kalamazoo County, an aggregate variable provided by the Kalamazoo County Health and Community Services. Multiple regression was applied to find out the major risk factors that were responsible for the lead poisoning in Kalamazoo by eliminating the factors that were not significant. For this purpose, the independent and dependent variables which were originally entered in an excel database were exported to SPSS to perform the multiple regression analysis. Here each observation is represented by a row in the data table and each variable is represented by a column. Before running the model, and testing the hypotheses, the distribution of observations for each variable was evaluated by creating histograms to test the assumptions of the regression model.

Procedure to Identify the Significant Factors

For proper use of regression analysis, it is necessary to check the collinearity diagnostics to verify a condition of multicollinearity exists. In some cases there are outliers which have a great impact on the model. For this reason it is necessary to save the leverage values of each observation (Tracts). Leverage values are over the rule-of-thumb value of $2p/n = 2 * 8 / 60 = 2.67$ (where p = number of independent variables and n = number of tracts) for 9 observations. After going through the data thoroughly I decided to remove observations 1 (Tract 1), 2 (Tract 2.01), 17 (Tract 15.04), 19 (Tract 15.07), 22 (Tract 16.04) and 36 (Tract 20.05) while leaving the remaining higher leverage observations as these represented cases with tracts with high percentage of children with elevated blood lead level.

After going through the regression output table, I rejected some of the hypothesized census tract level independent variables that were not significant. I then respecified the model leaving only the significant variables which were indicated as significant in the coefficient table. This process continued until I came up with a set of significant independent variables.

Assumptions of the Model

First of all it is necessary to calculate the correlation values of the independent variables to assess the degree of multicollinearity with the residuals. There should be lack of multicollinearity between the significant risk factors and the residuals. Also it is essential to plot a residual histogram to verify the assumptions of the multiple linear regression to assess the normality of the residuals. Another way of assessing the normality of the residuals is by the use of a probability plot. If the residual plot forms a diagonal straight line (at 45 degrees), then the residuals are likely to be normally distributed. Scatterplots of each variable with the residual could also be generated to verify the assumed risk factors in the model.

To analyse the distribution of lead poisoning thoroughly, it is important to know the demographic and housing characteristics of people by census tract in Kalamazoo County. For this purpose, I used ArcGIS to come up with a better graphical understanding of the county.

Analyzing the Demographic and Housing Characteristics

The shapefile of census tracts for Kalamazoo County was downloaded from the Michigan Center for Geographic Information. The attribute table provided the County's demographic characteristics that I used to create maps of the distribution of particular ethnic groups and also the distribution of median incomes for people living in each tract. It would have been better if the unit of analysis was the block group, but the smallest unit of shapefile that was available was the census tract, so this is what I used.

Besides demographic characteristics, identifying the nature of housing stock any particular study tract was essential for having a better perspective on the extent of the childhood lead poisoning problem in this county. The presence of old housing in large quntities (built before 1950s) and the percentage of the homes in any given census tracts in Kalamazoo that were for rent could be shown in the maps which helped me to further thoroughly analyse these tracts.

Summary of Goals

"...While epidemiology and demography possess a rich methodology, both disciplines are largely lacking a spatial perspective." (Tiefelsdorf, 2000: 151). It is important for modern social scientists to apply spatial statistics and GIS in order to solve the critical health problems that challenge our society. From the use of a GIS, that it was possible to calculate the location quotient which verified the risk tracts in this County. "Integration of spatial statistical analysis and geographic information systems (GIS) is an important next step in the development of spatial analysis technologies" (Brown, 1996: 149). A methodology that will able to predict the risk factors as well as identify special high risk in Kalamazoo County is necessary. This challenge is the main reason I chose multiple regression to narrow down the major risk factors that are responsible for lead poisoning, and also chose geocoding to find out the locations of these elevated blood lead level children in specific tracts.

CHAPTER IV

RESULTS AND DISCUSSION

Childhood lead poisoning is one of the more alarming environmental health problems impacting thousands of Michigan children. In 2001, it was estimated that on average everyday on average, 13 children under six years were affected by this childhood hazard. It was expected that if there had been complete testing, then the number would have risen to eighty-two children (Michigan Lead Safe Partnership, 2002). This is how frightening lead poisoning can be. So it is crucial for health researchers to look at the matter using a variety of techniques. As a geographer, my task to identify the actual location of the houses where children who have been tested and found to have high blood lead levels and to map these houses so that it is possible to recognize the houses which potentially still have exposed lead paint in Kalamazoo.

Identifying the Tested and EBLL Children in Kalamazoo County

Geocoding allows the researcher to pinpoint the actual location of the homes where lead paint may be a problem. Also, the relative location of the homes where children with elevated blood lead levels have lived in the past decade can be identified. After going through the interactive matching procedure, the address match was 93% for the tested 9,094 children which seemed to be satisfactory. From Table 4.1 it can be said that the total address matching rate was 85%, but the candidates having scores above 80 percent certainty is 71 percent which is shown in the following Table and the four quadrant maps introduced in the next section.

	Initial Counts	Initial %	Final Counts	Final %
Matched with Score 80-100	290	60	343	71
Matched with Score < 80	35	7	68	24
Unmatched	160	33	74	15

Table 4.1: Geocoding statistics

Most of the test was done within the Kalamazoo city area. I decided to split the County into four quadrants along the city: Northwest, Northeast, Southeast and Southwest to increase the scale of the map so they are easier to interpret.

In the following sections, I will describe the patterns associated with the homes where children with elevated blood lead levels in each of the quadrants of the City. No map of the County is used in this section due to the few cases outside the City limits.

The Northwestern Quadrant

The quadrant in Figure 4.1 has comparatively few homes with children with elevated levels of lead in their blood when compared to the other quadrants. It can be observed on the northern area of the map that the homes with children that have been tested for lead poisoning are located just along the township boundary of Kalamazoo that separates it from Cooper Township. There is another patch of at-risk homes just along the Northwestern side of Douglas Ave. If we view the areas in the southern region of US Hwy. 131, lead testing has been done for a higher proportion of children compared to the northern region due to the fact that major residential areas of this quadrant start just below Ravine Rd., a road parallel with the Kal Haven Trail State Park. In Kalamazoo City, (within the purple boundary line in the Figure 4.1), the at-risk homes are arranged in a scattered manner. It is obvious from the map that most of the homes with children with elevated levels of lead in their blood (≥10ug/dl) are found within the limits of Kalamazoo City. There is a cluster of homes with children with elevated lead levels children to the northern side of West Main St. and along Douglas Ave. There is also a cluster of homes that had children with high levels of lead in their blood located just along the U.S. Highway 131 and along West Main St.

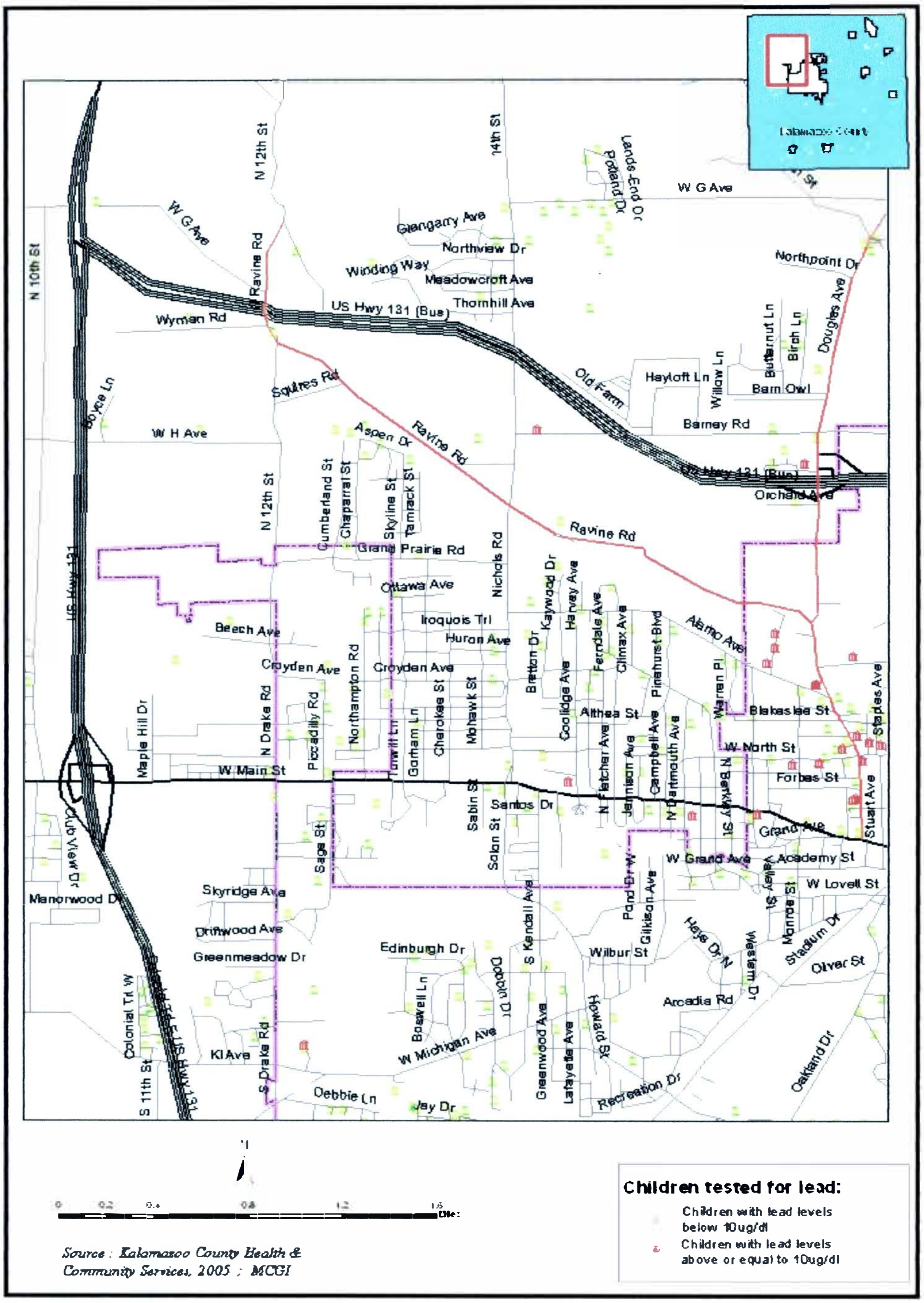


Figure 4.1: Distribution of lead poisoning children in Northwestern Quadrant of the City of Kalamazoo

The Northeastern Quadrant

This quadrant depicted as Figure 4.2 is the major concern for medical researchers who are interested in knowing the location of homes that could potentially contribute to lead poisoning cases in Kalamazoo County. It is observable that areas along Gull Rd., E Main St., King Hwy., E G Ave., Edison St. have a fairly random distribution of homes where children could be at risk. As was the case in the previous quadrant, lead testing takes place mainly for children living in the city of Kalamazoo. Along Westnedge Ave. and North Park St., most children were tested for lead poisoning. Also, the children in many of the homes located along Portage St. were included in the testing. It is evident from a look at Figure 4.2 that children living in these areas are at greater risk compared to the northern portions of the county. Almost 60 percent of cases of lead poisoning are situated in this quadrant. It is noticeable that there are two particular clusters of homes with positive cases within the city area. The northern cluster lies along North Westnedge Ave. and above West Main St. whereas the southern cluster is located within the area around North Park St. and Mills St. starting just below West Lovell Street and ending south at Miller Road. It is interesting to note that cases are very scarce outside the city limits and while there are also a few cases along Gull Rd., our main concern should be within the city proper old housing units are located in greater numbers.

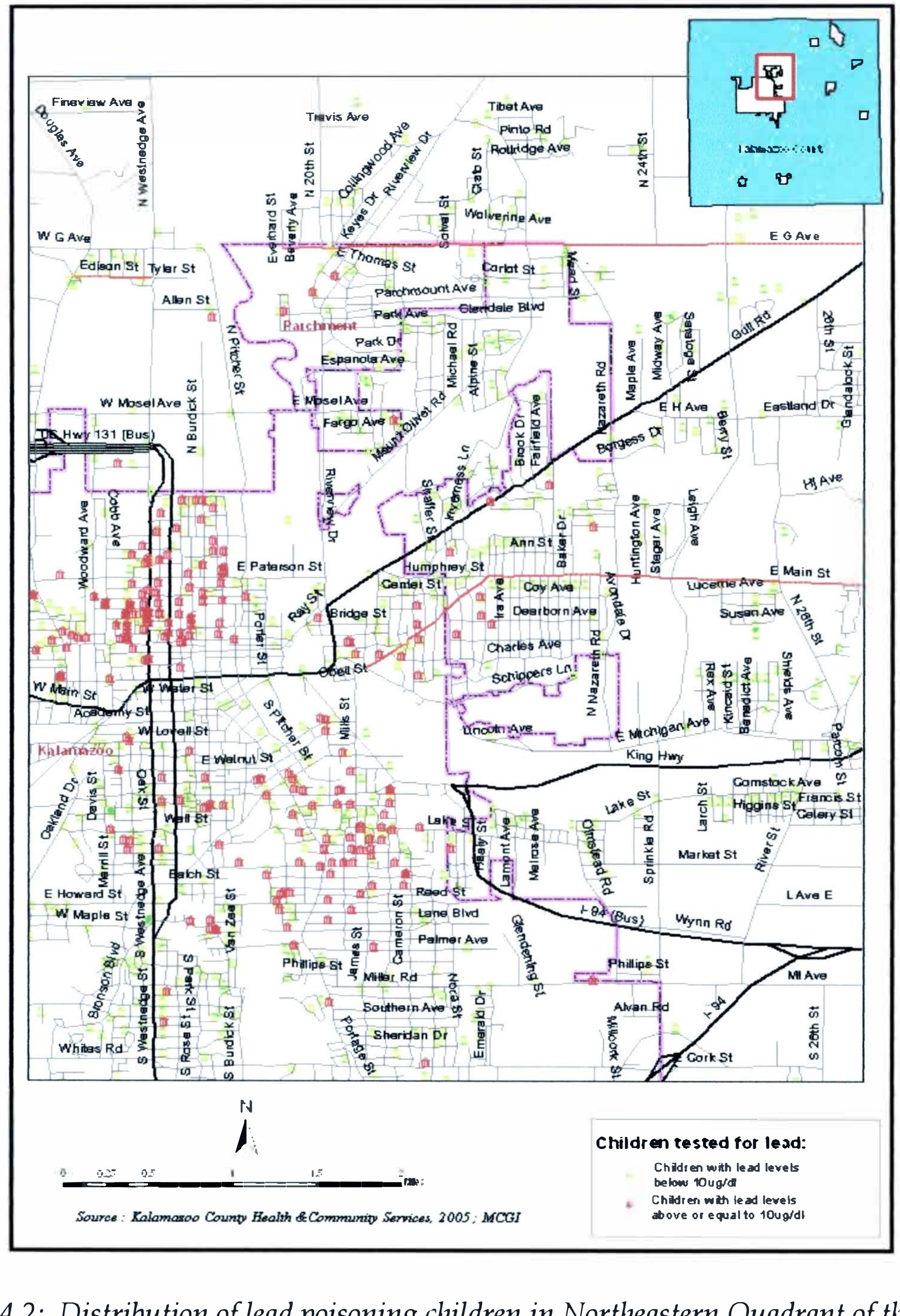


Figure 4.2: Distribution of lead poisoning children in Northeastern Quadrant of the City of Kalamazoo

The Southeastern Quadrant

This quadrant depicted as Figure 4.3 covers the southeastern portion of Kalamazoo city and the surrounding areas lying adjacent to the second quadrant. To some extent, it is exhibits a more or less continuous and similar distribution to the previous quadrant for areas within the city limit. As a result, it is obvious that homes with tested children in large numbers can be found along South Westnedge Ave. as well as along Portage St., Oakland Dr., and Angling Rd. It is interesting to note that there is a higher proportion of home with tested children in this quadrant as compared to the quadrants that have been discussed earlier. The southern cluster of cases of lead poisoning that was mentioned earlier in my description of the second quadrant can be viewed in the upper portion of the map. Similar to other quadrants, there are very few cases in the outer region of the city. From Figure 4.3, it is evident that there are possibly older homes along Kingston Dr., East Centre Ave., and Forest Dr., areas which should be given more attention in the future.

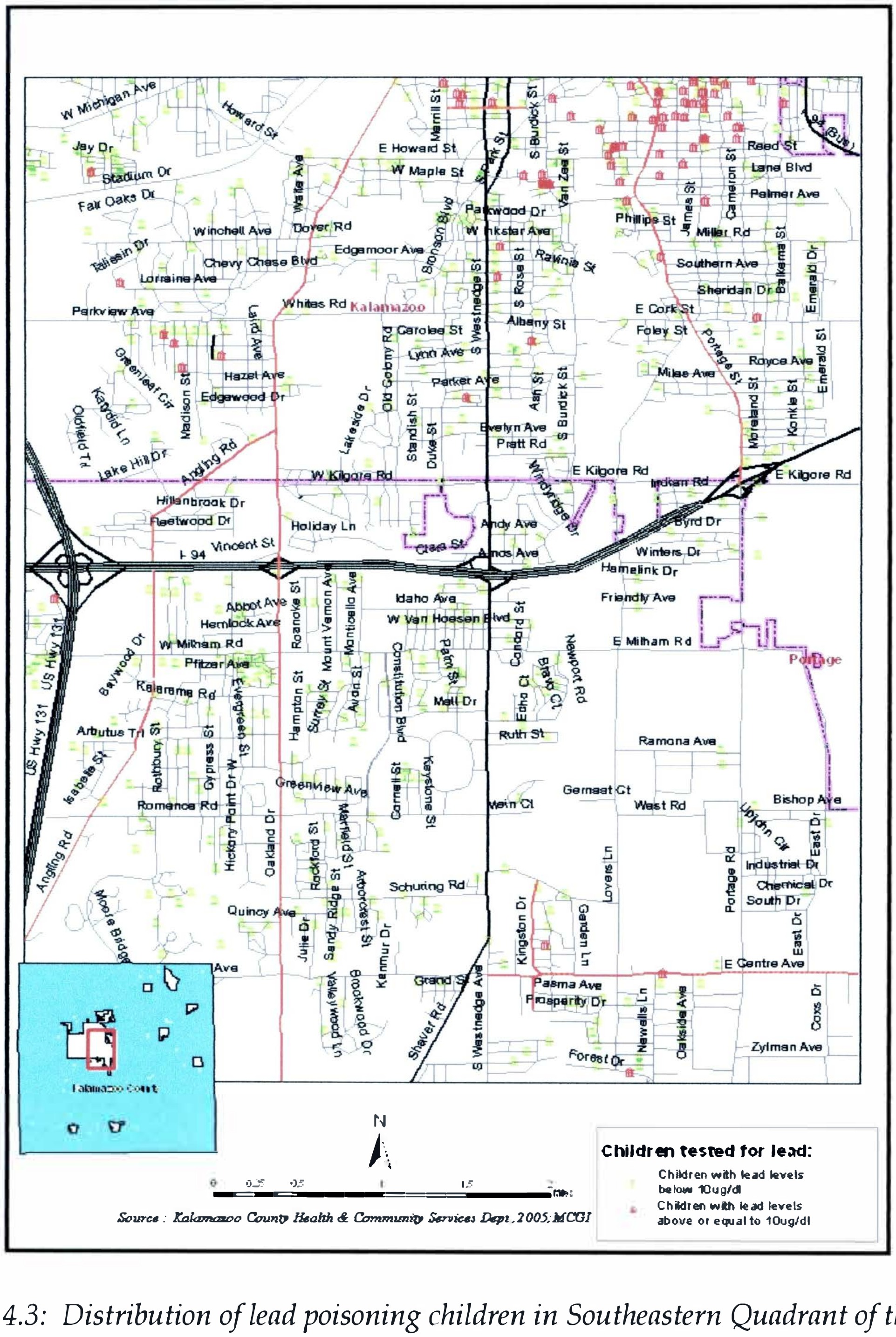


Figure 4.3: Distribution of lead poisoning children in Southeastern Quadrant of the City of Kalamazoo

The Southwestern Quadrant

This is located on the southwestern side of the city adjacent to the third and first quadrants. It has the fewest number of homes with children that have been tested for childhood lead poisoning. It is observable that the children living in homes along Stadium Dr., Winchell Ave., Parkview Ave. have participated in the city-wide lead screening program. In contrast, in the outer region of the city along the Us Hwy.131, fewer homes with tested children were found. Analysing the map thoroughly, it can be said that homes along the Stadium Dr. and Madison Streets are at greater risk than the children outside the city proper. In the outer region, homes with children with elevated levels of lead in their blood are mainly found in small numbers along South 11th St .

Overall, it can be concluded from this quick analysis of the four quadrants that the main risk regions lie within the city limits. It is here that public health workers should put more emphasis by screening more children and testing these houses by providing more awareness programs for the parents living in these areas.

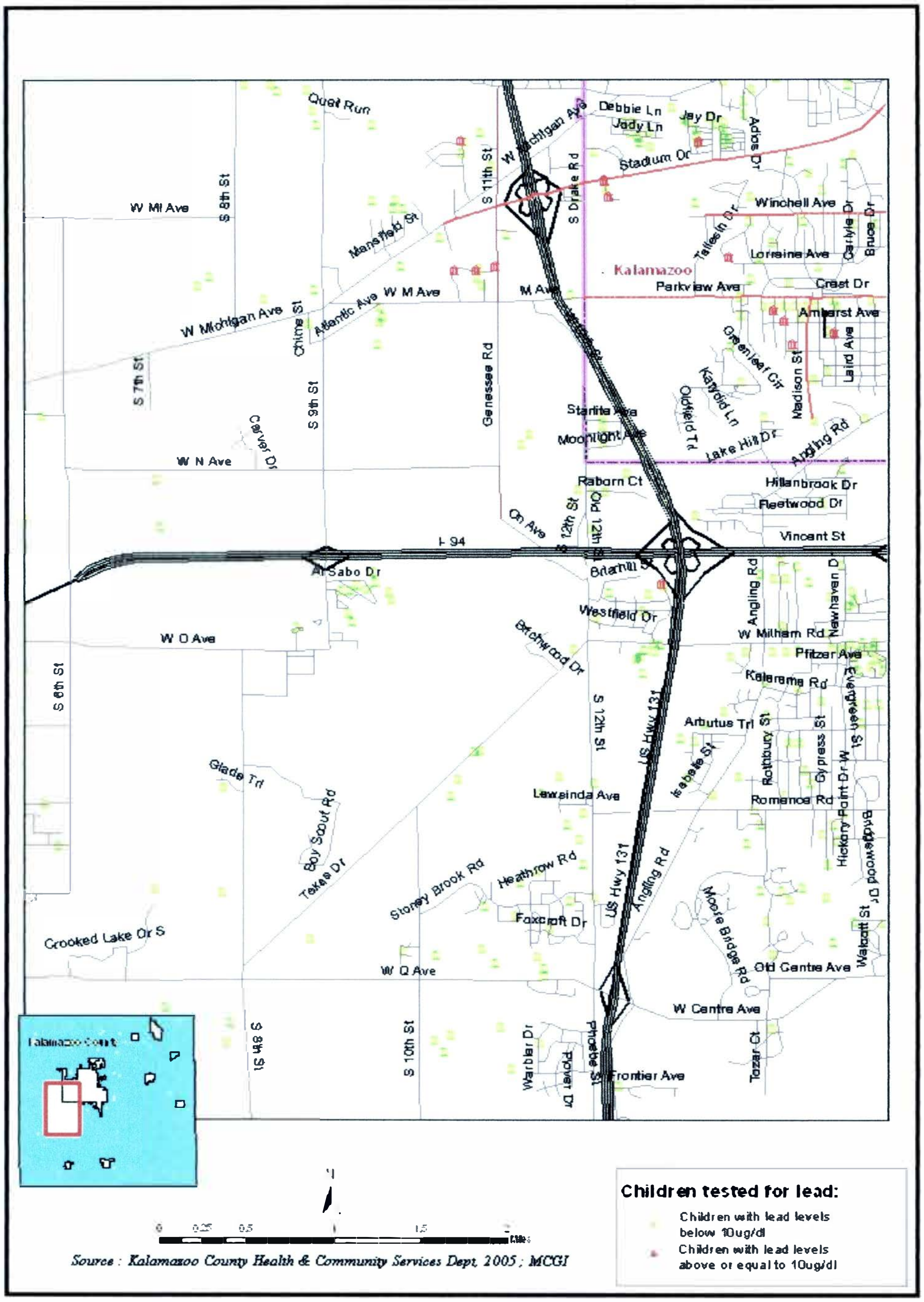


Figure 4.4: Distribution of lead poisoning children in Southwestern Quadrant of the City of Kalamazoo

The Small Northern and Southern Communities of Kalamazoo County

The small cities that are situated in the northern portion of Kalamazoo County are depicted as Figure 4.5 and are much less populated than the central city of Kalamazoo. For this reason, the number of homes with children tested for lead poisoning is quite low compared to Kalamazoo City. South Gull Lake, Richland, Augusta, and Galesburg are the northern communities included in the study but where few cases of lead poisoning in children were found. The same observation is true for the communities of the southern portions of the County where Schoolcraft and Vicksburg are located. Few children are tested, but only a very small proportion of children have elevated lead levels in their blood. Therefore County health workers can mainly focus on Kalamazoo City where children are most affected by lead poisoning.

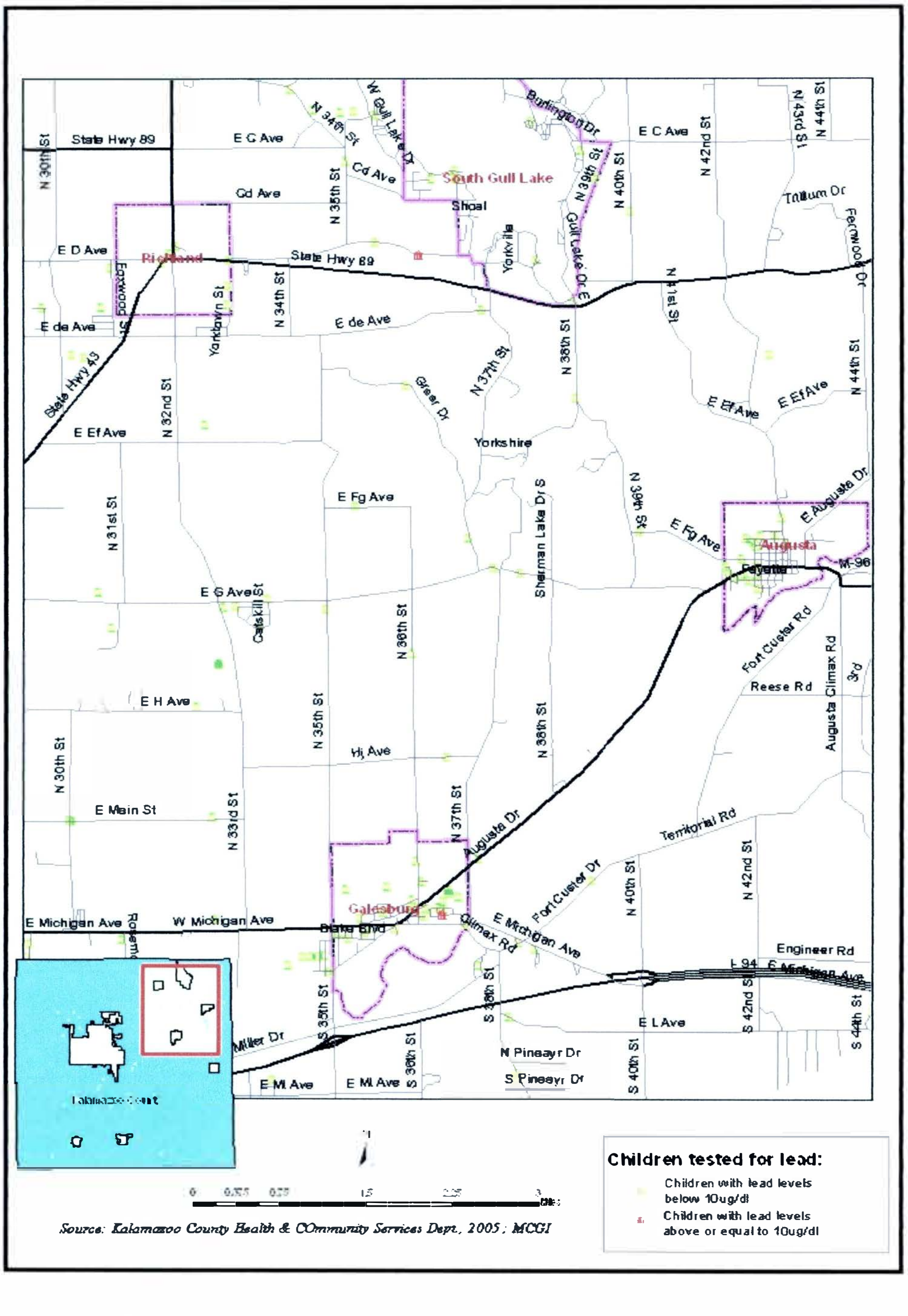


Figure 4.5: Distribution of lead poisoning children in Northern cities of Kalamazoo County

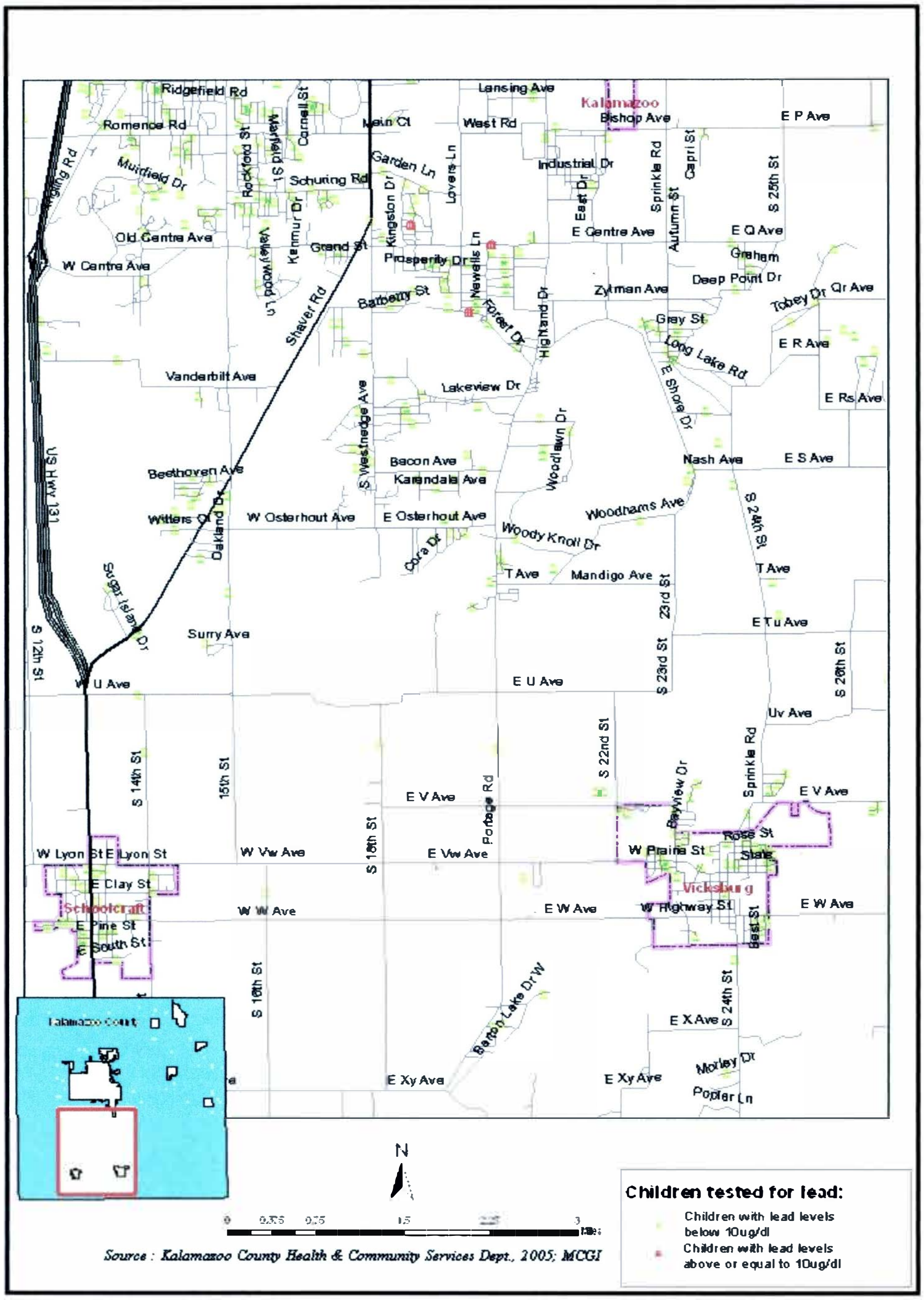
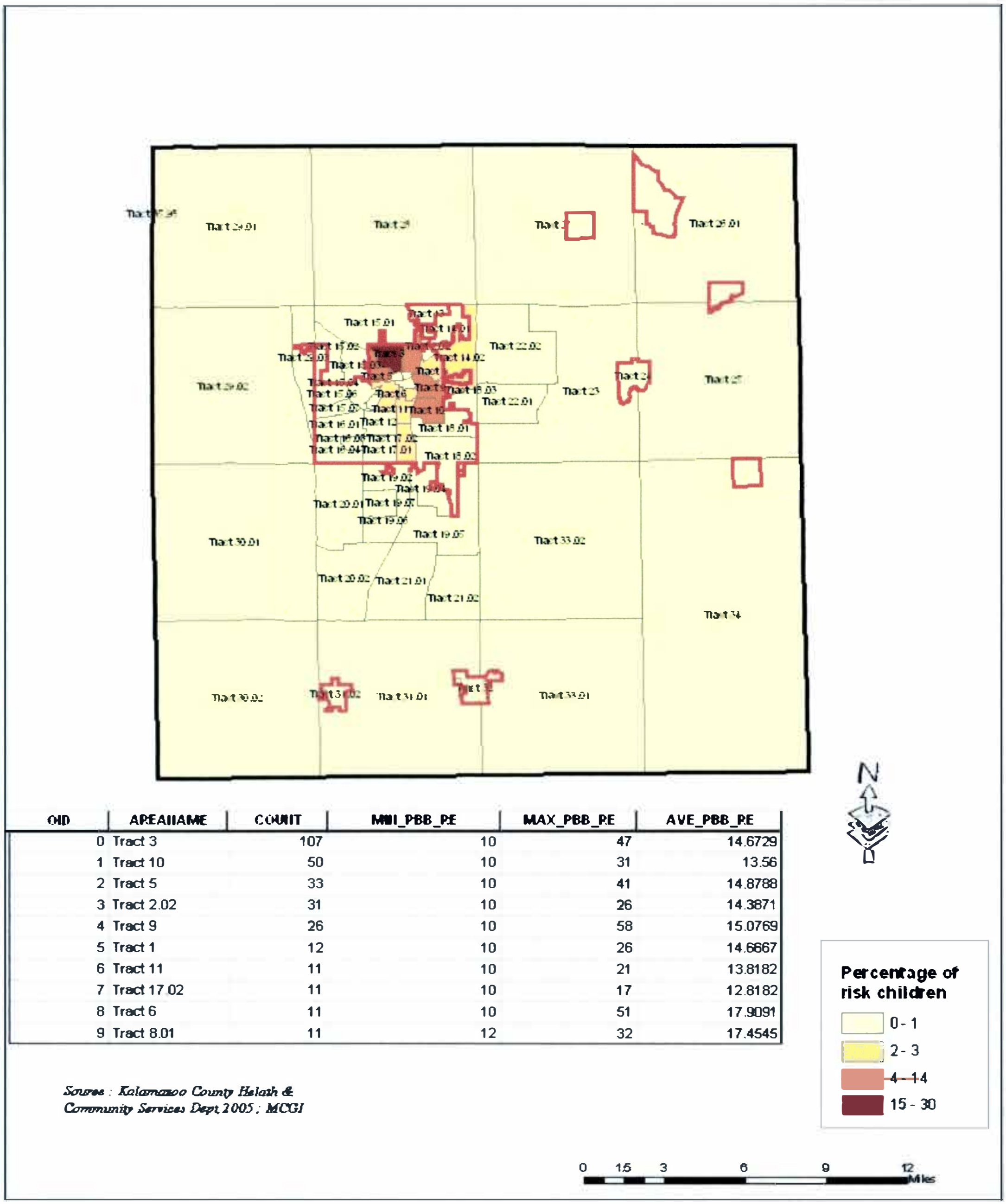


Figure 4.6: Distribution of lead poisoning children in Southern cities of Kalamazoo County

High Numbers of Cases within the City

It is also important to know where the greatest number of children with elevated blood lead levels are found. Figure 4.7 shows the census tracts that have the greatest number of children with lead levels in their blood ≥10 μg/dl. It can be observed from the table in Figure 4.7 that these tracts are concentrated in specific portions of Kalamazoo City. The northern and central tracts of this city have the highest numbers of cases with lead poisoning which is frightening for the families living in these areas. Homes in these areas should receive the first immediate remedial action by the outreach workers of Kalamazoo County.



OID	AREANAME	COUNT	MIN_PBB_RE	MAX_PBB_RE	AVE_PBB_RE
0	Tract 3	107	10	47	14.6729
1	Tract 10	50	10	31	13.56
2	Tract 5	33	10	41	14.8788
3	Tract 2.02	31	10	26	14.3871
4	Tract 9	26	10	58	15.0769
5	Tract 1	12	10	26	14.6667
6	Tract 11	11	10	21	13.8182
7	Tract 17.02	11	10	17	12.8182
8	Tract 6	11	10	51	17.9091
9	Tract 8.01	11	12	32	17.4545

Figure 4.7: Distribution of lead poisoning among children within the city tracts

The Lead Levels of Cases in the City of Kalamazoo

I developed four ranges for comparing mean lead levels in the City of Kalamazoo and used Figure 4.8 to find out where homes with children are located where they face the highest risk. It seems to be that many tracts within the city area have homes with children with elevated blood lead levels ranging from 10 µg/dl and 11-15µg/dl. These houses are randomly scattered in the tracts that are at risk. Children in this range represent a higher proportion of cases than those for children having more lead in their blood (above 15µg/dl). Therefore is clear that many children of Kalamazoo City are at initial stages of this debilitating disease which can without doubt be cured if proper action is taken.

According to the CDC, blood lead levels below 10µg/dl are not considered indicative of lead poisoning. Children having blood lead levels between 10-14µg/dl are in a border zone. For remedial purposes a detailed environmental history of the children should be taken. This is beyond the scope of this thesis but it is an important recommendation. In each case it is important to make sure the child's lead level does not go up overtime representing continued exposure. Lead prevention education should be provided to the parents through face-to face home visits at-risk homes by pediatric workers or by distributing brochures.

On the other hand, the higher lead levels ranging above 15µg/dl are mostly clustered in specific tracts (3, 5, 2.02,1, 9,10,11,8.01, and 6). Children with blood lead level in the range of 16 - 30 µg/dl need more careful follow-up. The health care provider should discuss types of interventions with parents to reduce lead level. Blood lead levels above 30µg/dl should be considered during a full medical evaluation including the collection of environmental and behavioral histories and tests for iron deficiency. The local public childhood lead poisoning prevention program leaders will often work as a team with pediatric health-care providers and the child's family to ensure appropriate environmental follow-up. Children with blood lead levels above 70 µg/dl constitute a medical emergency that preferably should be managed by someone with experience in treating children who are critically ill with lead poisoning. Fortunately the highest lead level in Kalamazoo County is 58 µg/dl but still assurances are needed to make sure such cases do not increase.

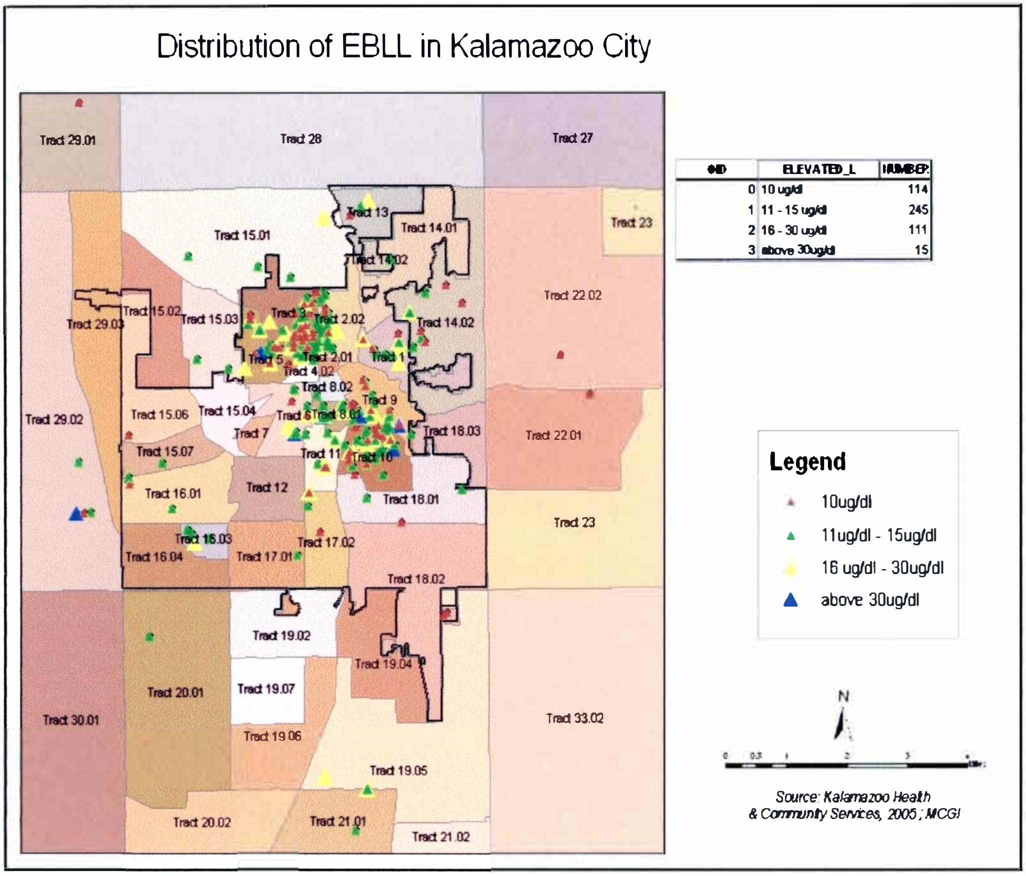


Figure 4.8: Distribution of different ranges of lead level in the City of Kalamazoo

Multiple Houses

"Multiple houses" are defined as individual houses that have more than one child affected by childhood lead poisoning. It can be observed from Figure 4.9 that Tract 3, Tract 10, Tract 5 and Tract 12.02 have higher proportions of multiple cases in houses than all other tracts. Also Tract 1, Tract 9, Tract 8.01, Tract 14.02 can be said to be risk areas for children. There are some specific street addresses for homes that have been provided to County Health experts for further evaluation. These homes have higher numbers of cases of lead poisoning at the same address. These houses are mainly apartment units which basically have the same amount of lead content. It is also observable that multiple houses with more than percentage of children with EBLL seven are located in Tracts 3, 5 and 17.02. After proper evaluation by health care professionals, these particular addresses must be investigated thoroughly, and if building code violations are found, then the owners should be prosecuted.

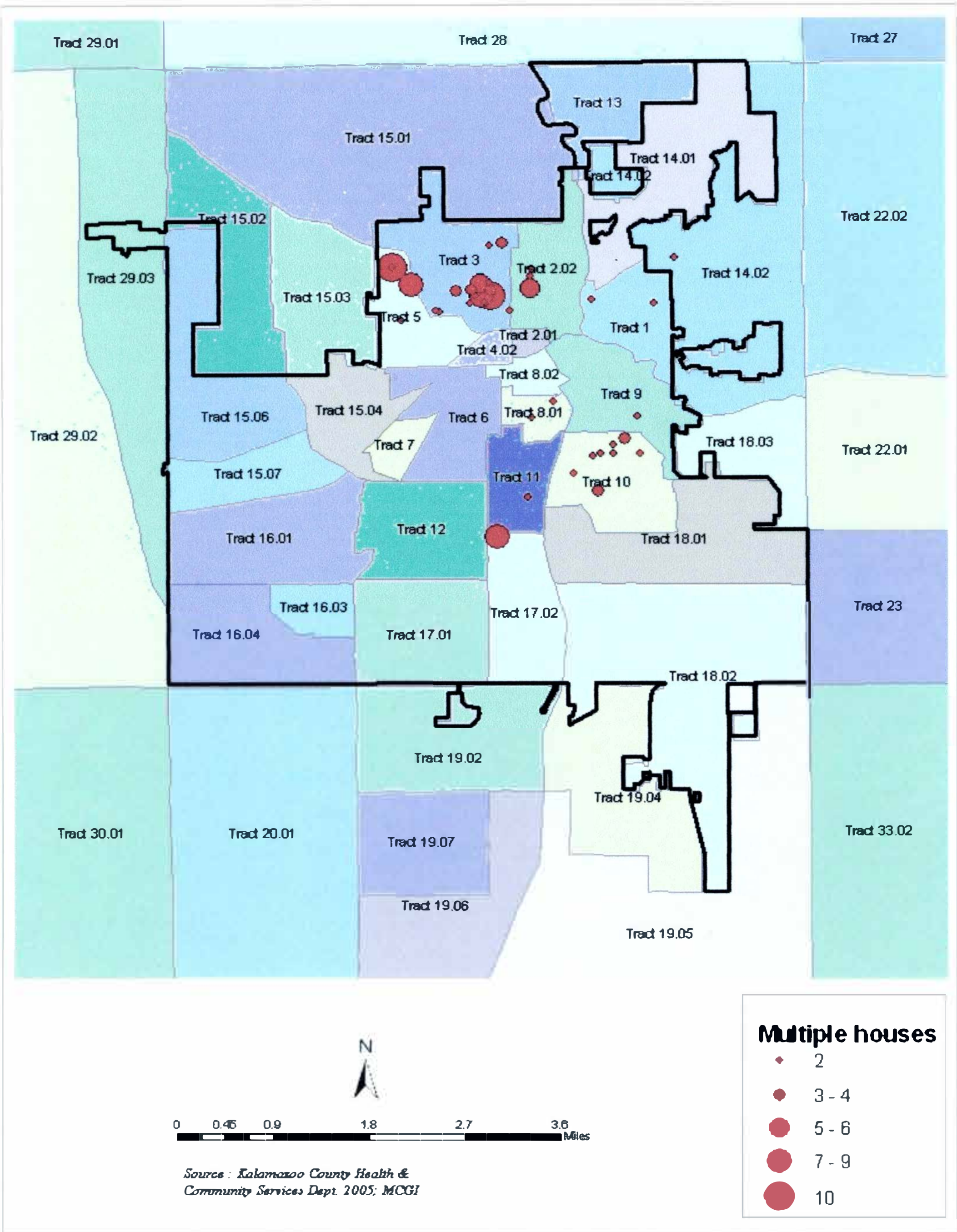
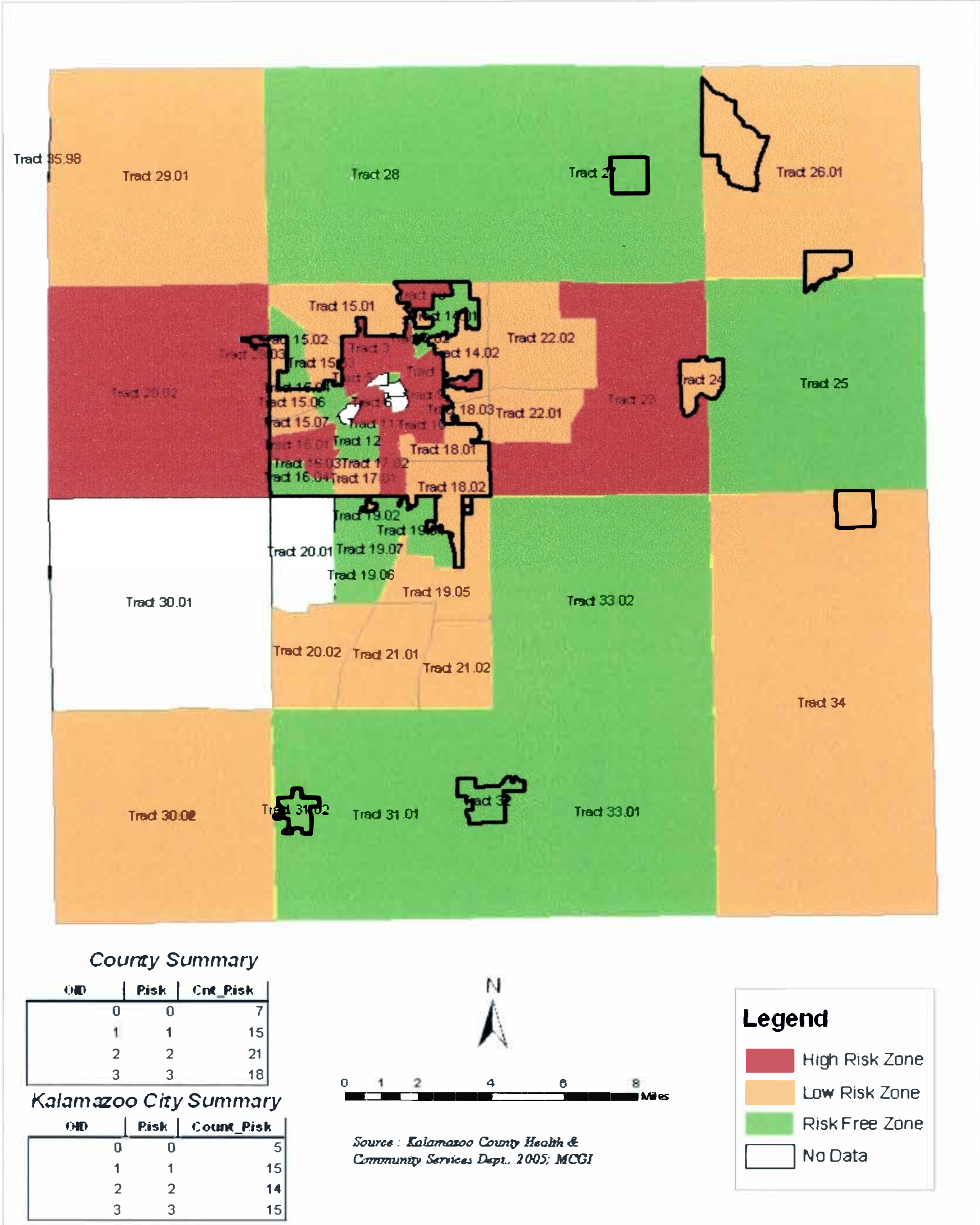


Figure 4.9: Distribution of multiple houses in the City of Kalamazoo

Location Quotient

Again, the location quotient (LQ) can be used to indicate the ratio of homes with children who have elevated blood lead level in a specific census tract as composed to the total number of children who live in that tract (as estimated by U.S. Census data). The LQ map in Figure 4.10 shows that homes with lead poisoning children are over represented in Tracts 1, 2.02, 3, 5, 6, 9, 10, 11, 13, 16.01, 16.03, 17.02, 29.03, 29.02 and 23. These are the high risk zones. As hypothesized, most of the tracts are located within the city limits. This map also shows some discrepancies as tract 29.02 and 13 should not be in the high risk zone but they are identified as high risk. This anomaly could possibly be due to the fact that families who use to live in the cities moved to homes in that specific tract for which the ratio of EBLL to the percentage of the children was higher than 1. It is important for health researchers to study the out-migration of the children who have EBLL. Also, it is observable that Tracts 1 and 9 have a higher percentage of homes with children at a higher risk of lead poisoning. It is also essential to consider the low risk zones where children may still face the risk of lead poisoning. These tracts are mostly located in the tracts adjacent to the city of Kalamazoo but within the County. The risk free zone that is indicated by the map represents the tracts which do not have homes with children with elevated blood lead levels. Outreach workers need not worry about the homes in those tracts, allowing more emphasize on the higher and medium risk zones to eradicate this critical childhood hazard. The tracts that show no data are simply the tracts that are missing in the US Census Bureau 2000. Recently, some specific tracts have been divided into two or more tract which are shown in the tract layer. This is the reason no data is indicated in tracts 8.02, 8.01, 7, 4.02, 20.01, and 30.1 while attribute table of multiple addresses show that there is tract 35.98 which seems to be an input error.



County Summary

OID	Risk	Cnt_Risk
0	0	7
1	1	15
2	2	21
3	3	18

Kalamazoo City Summary

OID	Risk	Count_Risk
0	0	5
1	1	15
2	2	14
3	3	15

Figure 4.10: Predictive risk model of lead poisoning in Kalamazoo County

Statistical Analysis

Before running the regression model and testing the hypothesis, the distribution of data must be evaluated by creating variable histograms. The histograms in APPENDIX C for independent variables from the U.S. Census at the tract level include average family size and the percent of children per household were normally distributed while those for the percent of the tract population who were Hispanic or African American, the percent of rental property, lack of plumbing, percent of poor population, percent of households run by single mothers are positively skewed. Whereas the histogram of percent of old housing was slightly positively skewed.

Multiple regression analysis is concerned with the dependence of one variable on a set of independent variables (Appendix B).

The typical multiple linear regression equation is written as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_1 X_2 \ldots\ldots\ldots\ldots + \beta_k X_k + e_i$$

Where β_0 is the intercept term

β_1, β_2, β_k are the regression coefficients

X_1, X_2, X_3 are the independent variables

e_i are the residuals of the model

The Hypothesis for the overall model:

Null, H_0:$\beta 1 = \beta 2 = \beta 3 = \beta 4 = \beta 5 = 0$

No relationship between the dependent variable and independent variables

Alternate, Ha : $\beta i \neq 0$

At least one variable is associated with dependent variable.

Hypothesis for each variable β:

For the percent of African American and Hispanic,

Null, H_0: $\beta 1 < 0$

No relationship with the dependent variable

Alternate, Ha: $\beta 1 > 0$

There is a relationship with the dependent variable

For the Percentage of children under 6 years variable,

Null, H_0: $\beta 1 < 0$

No relationship with the dependent variable

Alternate, Ha: $\beta 1 > 0$

There is a relationship with the dependent variable

For percent of single mothers variable,

Null, H_0: $\beta 1 < 0$

No relationship with the dependent variable

Alternate, Ha: $\beta 1 > 0$

There is a relationship with the dependent variable

For The average family size variable,

Null, H_0: $\beta 1 < 0$

No relationship with the dependent variable

Alternate, Ha: $\beta 1 > 0$

There is a relationship with the dependent variable

For poor population variable,

Null, H_0: $\beta 1 > 0$

No relationship with the dependent variable

Alternate, Ha: $\beta 1 < 0$

There is a relationship with the dependent variable

For percentage of old housing (pre-1950) variable,

Null, H_0: $\beta 1 < 0$

No relationship with the dependent variable

Alternate, Ha: $\beta 1 > 0$

There is a relationship with the dependent variable

For percent of rental status variable,

Null, H_0: $\beta 1 < 0$

No relationship with the dependent variable

Alternate, Ha: $\beta 1 > 0$

There is a relationship with the dependent variable

For percent of lack of plumbing facilities variable,

Null, H_0: $\beta 1 < 0$
No relationship with the dependent variable

Alternate, Ha: $\beta 1 > 0$

There is a relationship with the dependent variable

From the scatter plots in Figure 4.11 and Figure 4.12 it can be seen that there is a strong relationship between the mean percent of African American and Hispanic households in a tract and the percent of children with lead poisoning as compared to the total number of children estimated from census data. As a relationship exists between the percent of housing that is old (<1950) and the percent of children with elevated lead levels.

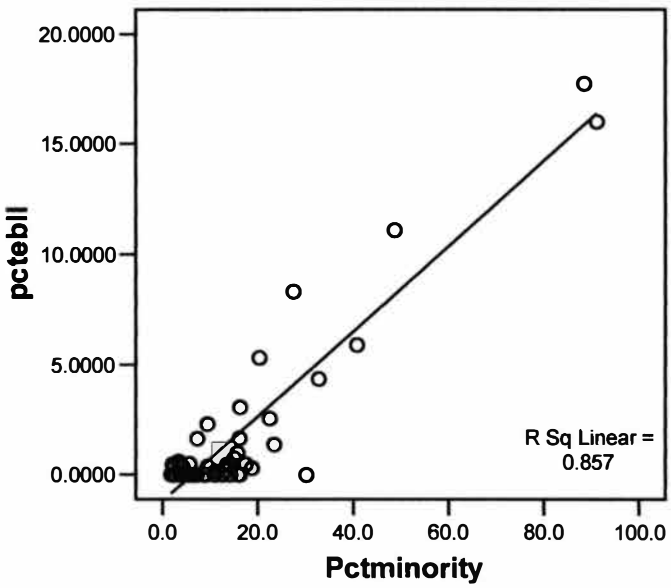


Figure 4.11: Scatterplot of percentage of African American and Hispanic

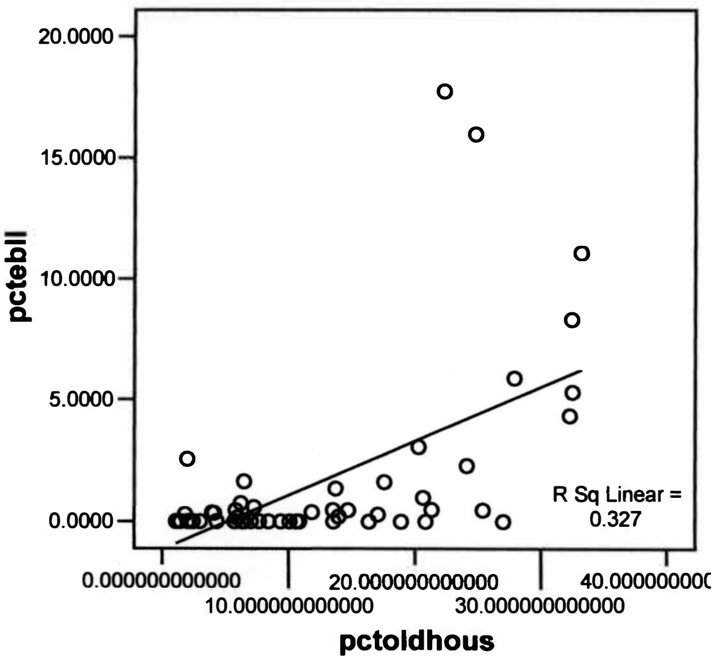


Figure 4.12: Scatterplot of percentage of old housing with percent of lead poisoning children

A Pearson product moment matrix correlation was generated to examine the relationship among all variables. For the percent of homes with a lack of plumbing and the percent of old housing, a significant relation with other variables $p < .05$ occurred. The relationship between the percent of the population that are reported in the cases as minorities and the percent of old housing is quite significant ($p = 0.001$).

For estimating the regression model, I decided to use the background stepwise routine provided in SPSS. This routine introduces one independent variable at a time in order to find an appropriate model with the selected independent variables. Again the variables used are all at the census tract level.

By running the regression model it can be clearly seen that the dependent variable is closely related to my chosen independent variables. From the First Model summary and the ANOVA table in APPENDIX D it can be determined that

Model diagnostics adjusted R square = .897
Std. error of the estimate = 1.2
F = 58.83
and P = 0.00 (two tailed) Significant at .05 level

Coefficients[a]

Mode		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Confidence Interval f		ollinearity Statistic	
		B	Std. Error	Beta			ower Boun	pper Boun	olerance	VIF
1	(Constant)	-12.462	3.721		-3.349	.002	-19.956	-4.967		
	Pctminority	.155	.021	.746	7.402	.000	.113	.198	.191	5.239
	Pctchildren	-.260	.141	-.147	-1.846	.072	-.543	.024	.308	3.252
	pctfemale	.206	.204	.104	1.008	.319	-.205	.618	.181	5.538
	avfamsz	4.337	1.434	.220	3.025	.004	1.449	7.225	.366	2.729
	pctoldhous	.056	.028	.144	2.018	.050	.000	.112	.382	2.620
	pct lack plmg	-.318	.347	-.055	-.917	.364	-1.018	.381	.530	1.887
	pct poverty	.095	.156	.040	.612	.544	-.218	.409	.450	2.222
	percentagere	-.068	.128	-.033	-.533	.597	-.325	.189	.519	1.927

a. Dependent Variable: pctebll

Table 4.2 : Initial regression model of lead poisoning variables

The overall regression model is significant. Thus I can reject the null hypothesis and accept alternate hypothesis. There is relationship between the independent variable and at least one independent variable (Appendix C2). From the Table 4.2 we derive the following equation :

Pct Ebll = - 12.46 +.155 (pct minority) – .26 (pct children) + .206 (pct female) + 4.337 (family size) + .095 (pct poor pop) +.056 (pct old hg) - .01 (pct rental) - .318 (pct lack plmg)

In the case of the final independent variable, the percentage homes that are rental units and the percent of the population living below the poverty level seems to be least significant. So, the alternate hypothesis is rejected and the null hypothesis is accepted. It is assumed that there is no relationship among the dependent variable, the percent of children with lead poisoning in a tract and the independent variables, the percent of houses that are being rented, and the percent of population below poverty level. Thus these two independent variables are rejected.

In the same way, I remove other independent variables until the independent variables are significant. By running the fourth regression model it can be said that

The adjusted R square = .889
Std. Error of the Estimate = 1.24
F = 213.6 and P = 0.00 (two tailed) Significant at .05 level

The equation of the final model is:

Pct of children with Ebll = -1.952 + .174 (Pct minority) + .082 (pct old hg)

A further assumption of multiple linear regression is that the residuals are normally distributed. In this experiment, the residuals are normally distributed. Also it is observed from the correlation table of the significant variables that there is a very slight correlation between the significant variables and the residual. This improves confidence in the model.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	-1.952	.283		-6.892	.000	-2.521	-1.384		
	Pctminority	.174	.011	.835	16.463	.000	.153	.195	.813	1.229
	pctoldhous	.221E-02	.020	.211	4.157	.000	.043	.122	.813	1.229

a. Dependent Variable: PCTEBLL

Table 4.3: Final regression model of lead poisoning variables

From the Table 4.3, it is evident that the percentage of minorities living in a census tract is positively related to the percent of children exhibiting elevated blood lead levels. This is probably due to the fact that some African Americans and Hispanics may live in deteriorated housing and they are not aware that lead paint is present in their rental houses. Old housing seemed to be the main risk factor. I expected the percentage of rental housing to also be a factor but this variable was not significant. Maybe the reason could be that the variance is low and so it does not covary with elevated blood lead levels in children. I also expected the percentage of the population below poverty level to be a factor (Bashir, 2002) but it was not significant enough to reveal a relationship at the census tract.

Housing Characteristics

Old housing units that were built before 1950 are designated as at-risk houses. This old housing stock was mainly located in urban areas of the County. Due to the lower median value of these structures, low income people tend to dwell in these deteriorated places. From Figure 4.13, it was estimated that the Midwest had the second largest supply of housing stock (23.3%) in which it had relatively larger proportion of old housing (12.1%) and a lower proportion of new housing (14.5%) compared to other regions (American Housing Survey, 2001).

If the housing characteristics of my study area are taken into consideration an interesting aspect can be identified. The distribution of the percentage of old housing of Kalamazoo County is mapped on the basis of census tract level as Figure 4.14. It can be observed from the "old housing" map that tracts 2.02, 2.01 and 11 have highest percentage of old housing. From Figure 4.14 it is evident that that old housing units are more often located within the city boundary where the high concentrations homes with children with elevated lead levels in their blood is observed.

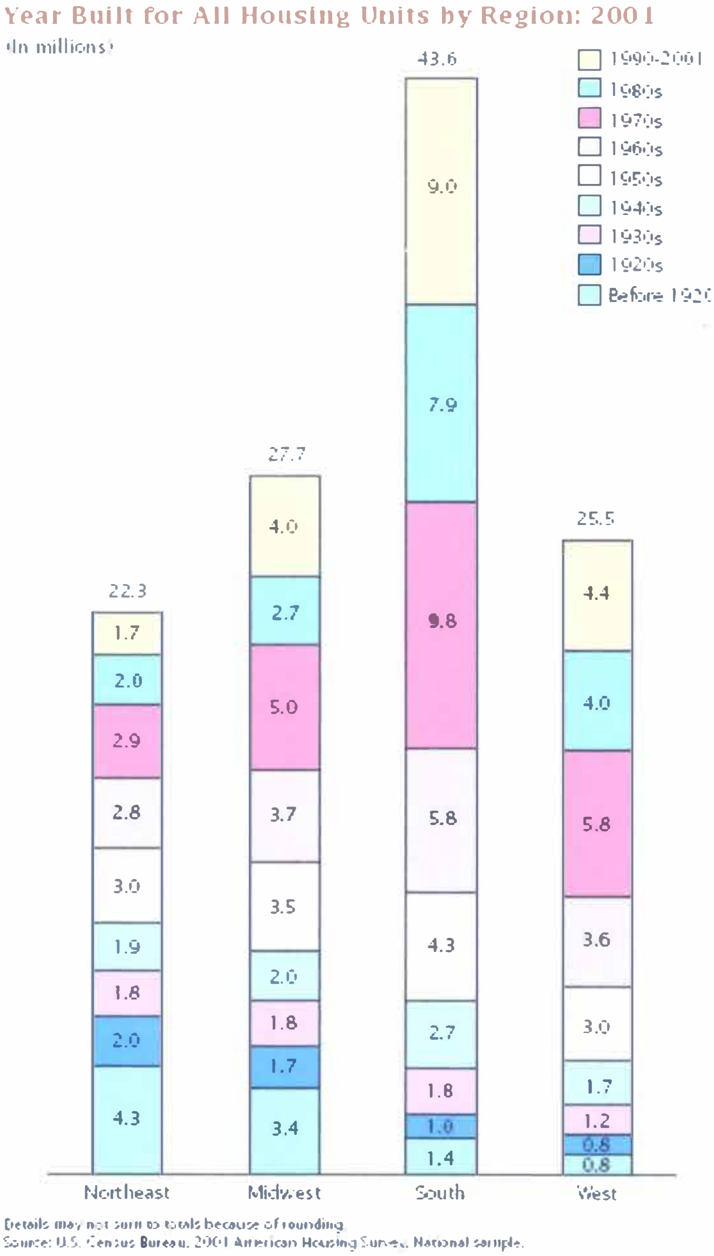


Figure 4.13: Bar diagram of percentages of old and new housing in U.S. Regions

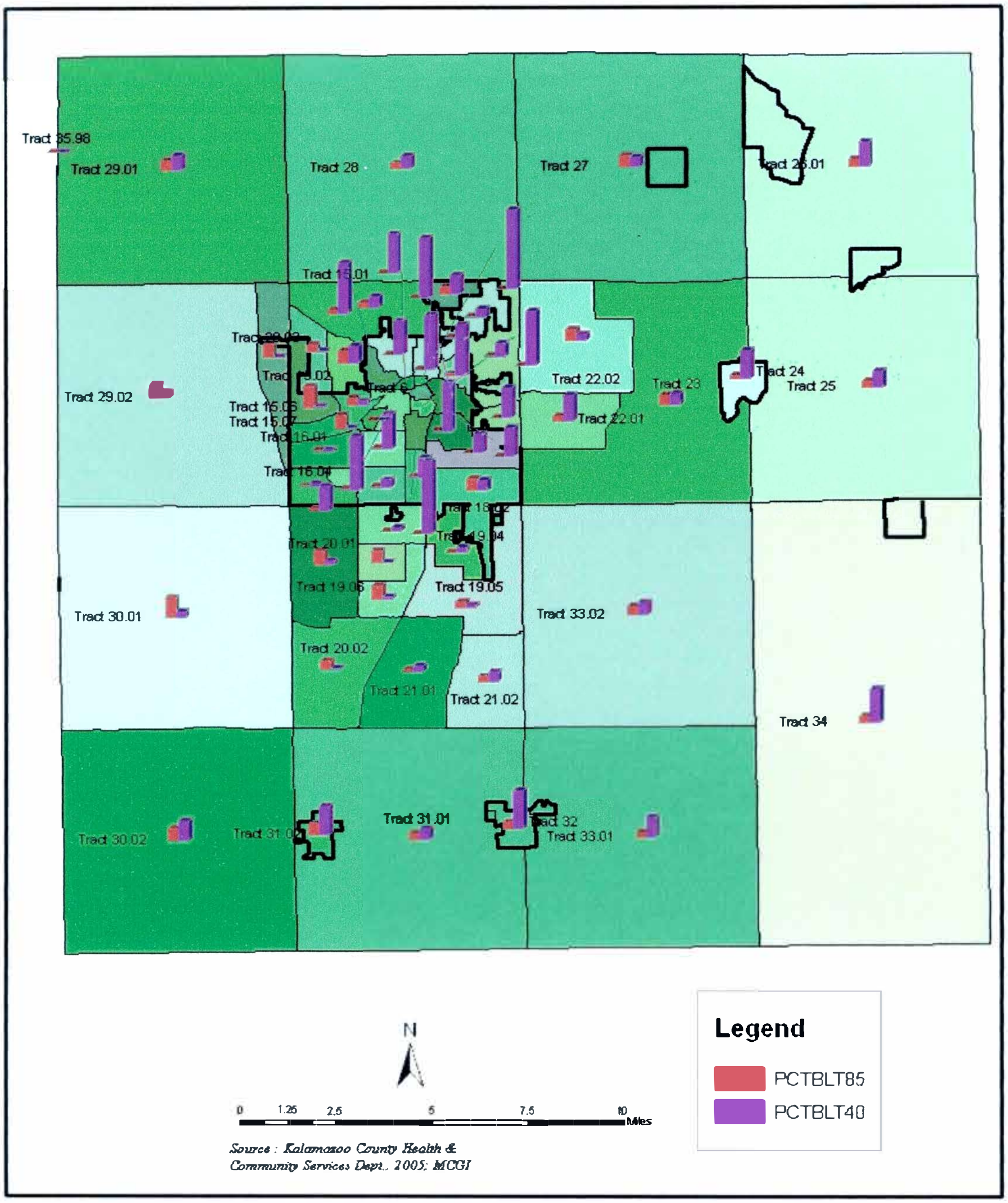


Figure 4.14: Distribution of old housing structure in Kalamazoo County

If the outcome is compared with that for tracts with mostly new housing, it is apparent that tracts with a higher percentage of houses built after 1985 are located in the western side of Kalamazoo City and later spread to the surrounding tracts outside the City. Other cities like Schoolcraft and Vicksburg that are located in the southern part of the county have higher percentages of new housing when compared to other cities. This explains why there are hardly any homes with children with elevated blood lead levels in these growing cities. This map of the distribution of old housing strongly reflects the positive relationship between older houses and childhood lead poisoning which was already statistically proven significant as a major risk factor in Kalamazoo County. The second major risk variable that has also been statistically proven is the varied ethnicity of the population living in these unhealthy housing condition.

Demographic Characteristics

The distribution of minorities is an important factor in predicting the risk of elevated blood lead levels in children in Kalamazoo County. It can be observed in Figure 4.15, and based on evaluation of census data, that minorities more often tend to live in houses that are in poorly maintained condition when compared to the white majority community. This could be due to the fact that African Americans or Hispanics cannot own or rent better housing which dooms them to live in old housing units which are more affordable than the new homes.

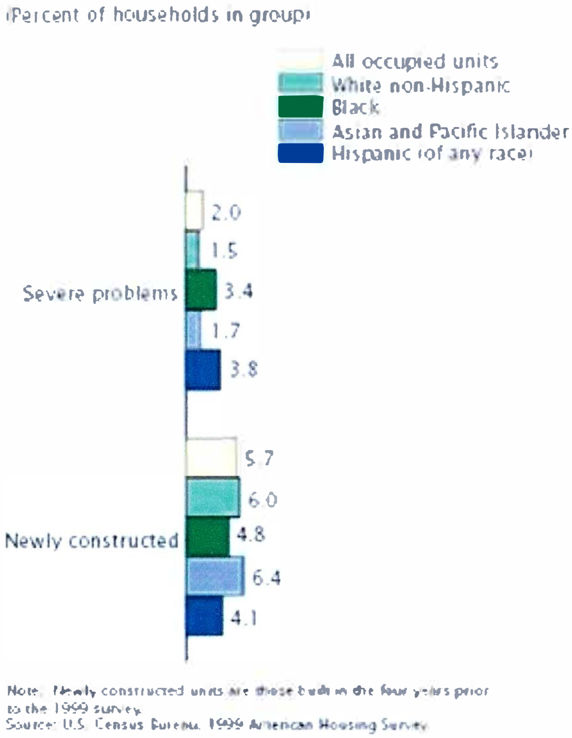


Figure 4.15: Characteristics of housing units by race

In general, African American and Latin American population are the major ethnic groups that live in Kalamazoo County. So I used the percentages of these two ethnic groups, derived from the U.S. census at the census tract level, as key variables. It can be observed from Figure 4.16 that Tracts 2.02, 3, 1 and 7 have high percentages of minority residents. It is interesting to note that these tracts correspond to homes with a high percentage of children with elevated blood lead level. Tract 3 has the highest number of cases (107) whereas Tracts 2.02 has 31 lead poisoning children.

For analyzing this risk factor, the second map represents a better understanding of the ethnic distribution of the actual elevated blood lead level children in Figure 4.17. The bar chart shows the percentage of minorities residing in each of the tracts. It can be said that although we have previously mentioned that Tracts 3 and 2.02 have high percentages of minority residents; there are also high percentages of homes including children with lead poisoning in tracts 1, 9 and 10. These three tracts have comparatively lower minority population. These tracts are also effected by the high percentage of old housing structures found in these tracts. Risk factors which are responsible for the percentage of EBLL children in Kalamazoo County can then be considered to analyse the risk model of childhood lead poisoning in this very study area applying location quotient.

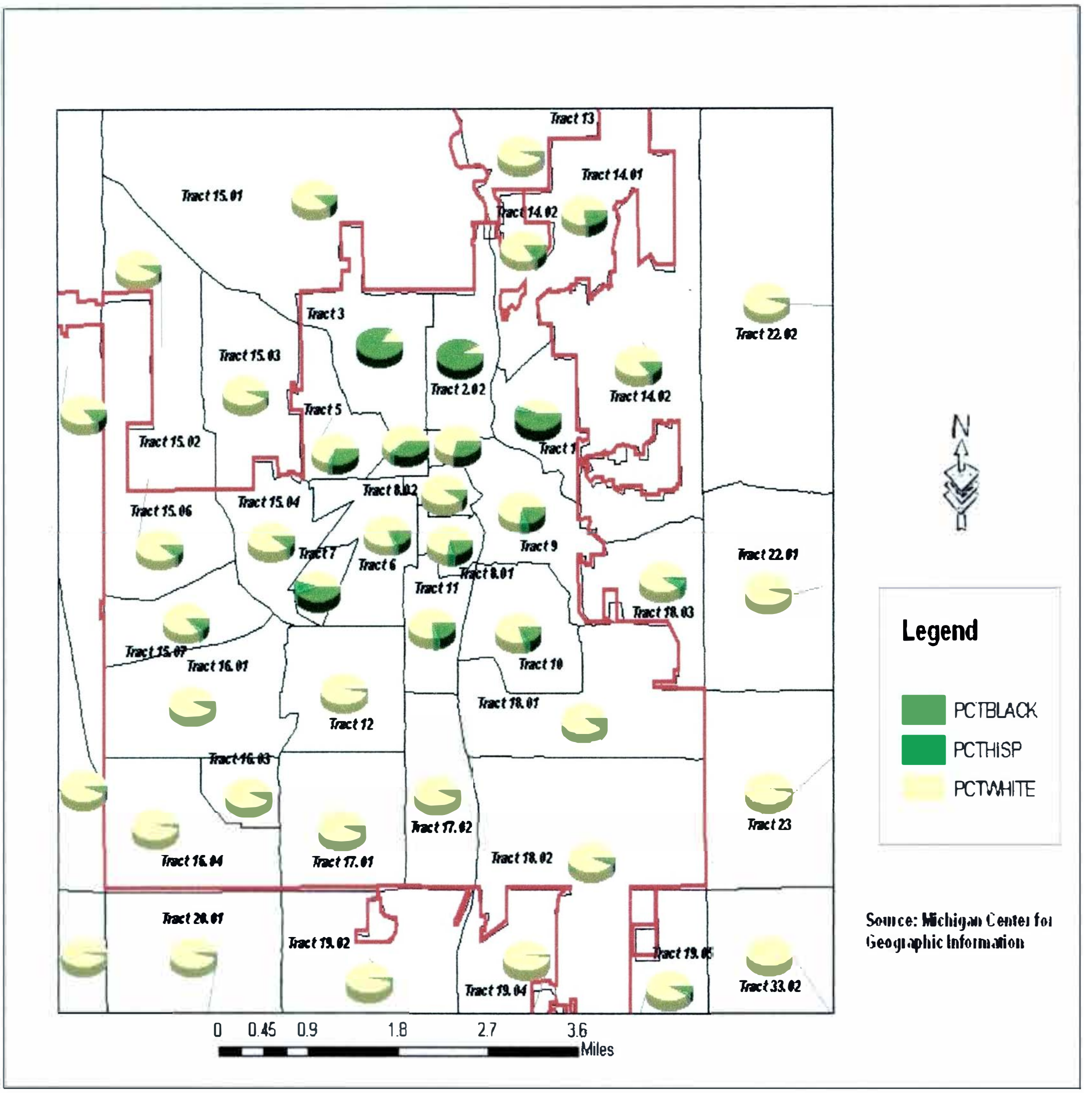


Figure 4.16: Pie diagrams of demographic characteristics in the City of Kalamazoo

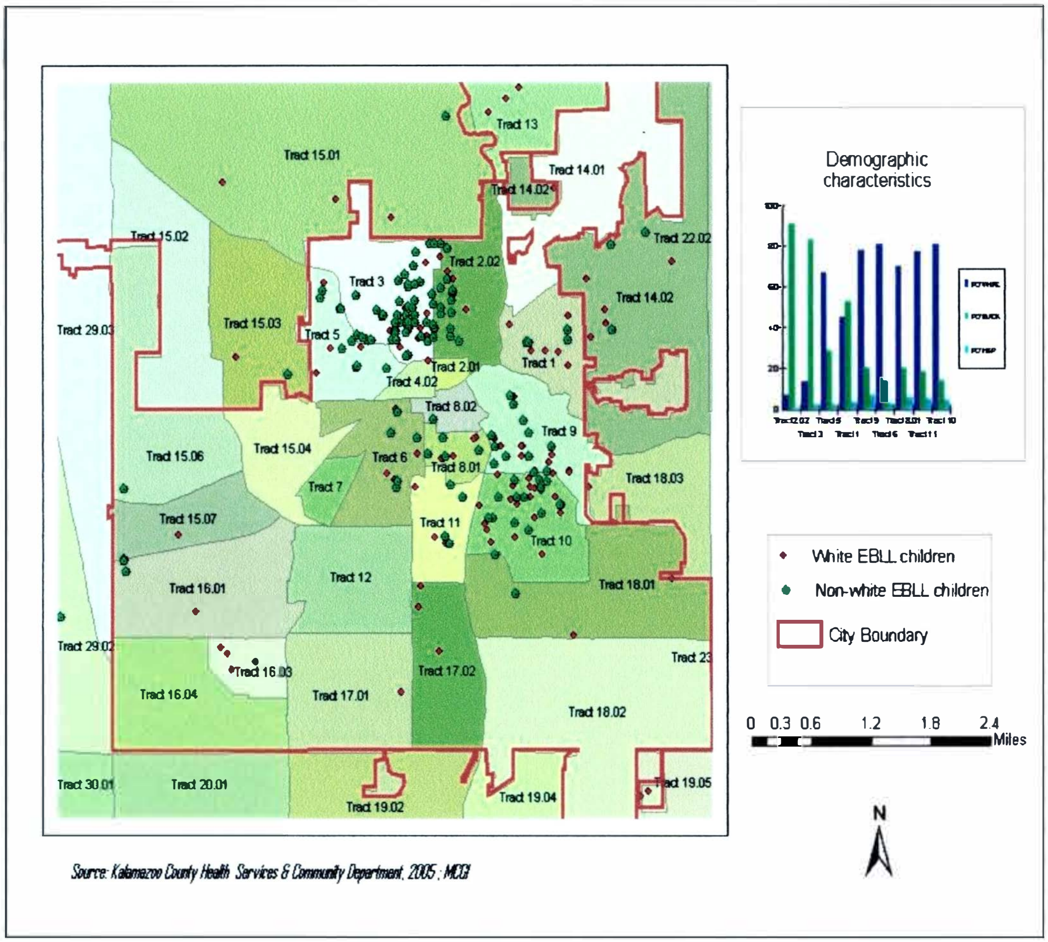


Figure 4.17: Distribution of demographic characteristics in the City of Kalamazoo

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

Conclusion

In the 1940s, it was a challenging job for health researchers to convince parents of the danger of lead in children's toys, cribs and windowsills due to paint surfaces having more than 50% of lead by weight. After many dreadful incidents resulting in childrens' disabilities, the New York Daily News reported in an article that 10 Brooklyn children were killed by lead poisoning in 1955 alone. This was followed in July 1956 by an effective campaigning "Don't Let YOUR Child Get Lead Poisoning," promoted by Parade Magazine that was also broadcasted reported by the CBS television network. From that day, the public became more aware of lead poisoning. Since then, health departments and the federal government have implemented rigorous action plans to reduce lead from the major sources that are harmful for both children and adults. But we cannot stop here. There are still half a million children in US alone who are victims of this dreadful and curable disease.

As my study area was based on the homes and children of Kalamazoo County, I am going to mainly summarize the findings of my thesis in this chapter for this county.

First of all, it was evident from the geocoding procedure that 62.5 percent (303 cases) of elevated blood lead level children were mostly found within the city portion of the county. This is due to the fact that the oldest housing stocks are located in this multi-ethnic and most densely populated urban area. Second, it was statistically proven, based on U.S. Census data, that children coming from minority families are more susceptible to lead poisoning than the children from other groups. This could be due to a range of factors, both cultural and physical, and also due to the environment they live in. Also, it was established from multiple regression analysis that pre-1950 housing was found to be the major risk factor in this childhood hazard. This indicates that old homes often have paint with harmful lead which effects the infants as they tend to exhibit pica behaviour. Later in my research, these demographic and housing risk factors of Kalamazoo County analyzed determine if these factors truly have impacts on the distribution of lead poisoning in Kalamazoo County. Those tracts that have high percentage of minority groups do show higher numbers of homes with EBLL children compared to other tracts which have fewer African American and Hispanic children. Also, it is obvious from the housing map that those tracts having a grater percentage of older houses with lead paint tend to have higher numbers of EBLL tracts which are located in Kalamazoo city. The use of the location quotient (LQ) identified the city area to be the main risk zone while the surrounding tracts seemed to be the next risk zone that should also be of concern to public health workers. The non-urban tracts that are located in the northern and southern regions of the county are less likely to have any lead poisoning health problems. So, the public health department should focus mainly on the high risk zones by taking the immediate action of testing houses, screening more children, and using regular follow-up tests. This action could eliminate this harmful disease from this county in no time if the public health workers promptly test children in the zones that are at greater risk.

Limitation of the Study

The main task for my research was address matching homes which could have been more satisfactory if the tax assessor database was used instead of zip codes. This is highly recommended by the CDC. Also, while identifying the major risk factors, I realized that it would have been better if there were soil sample data which could indicate if soil dust triggers lead poisoning as well. In case of the housing maps, it can be observed that the units represent census tracts, but if the tax assessor database was applied then it would have been more comprehensive by showing the exact housing age of individual homes in this county. I also tried to create risk zones for lead poisoning which basically provides a rough idea of the potential risk of this health situation in particular area (based on census tracts). A more accurate analysis would have been possible if I applied Satscan which requires mainly three variables: children population, case population (EBLL children) and the coordinates of the cases. These data were not available. The output which is the cluster map of childhood lead poisoning in this region is more accepted by medical geographers working in this area.

Recommendations

Michigan legislation already has many policies that are appropriate for eliminating this dreadful health problem. But the implementation rate is not up to standard in comparison to the rate that this alarming problem still affects the children of Kalamazoo. In the following section I would like to suggest some easy and cost effective methods for trying to eradicate lead poisoning. These recommendations may seem, of course, to be a bit ambitious but I believe they are possible to implement.

1. Further Develop a GIS System in the Kalamazoo County Health Department

This study has applied GIS and spatial analysis successfully. Based on this methodology, and these results and other GIS techniques, GIS can be implemented for the continuous analysis of lead poisoning and other public health research. GIS personnel should be hired to assist public health workers to get their job done more efficiently and help maps up-to-date with the most current data from the State of Michigan.

2. Provide Comprehensive Guidelines to Public Health Workers

a. Screening should be done to cover all Medicaid children as much as possible

b. EBLL children should be provided with remedial action on a routine basis by health professionals.

c. Houses that are at risk should be introduced to a health management program, possibly these landlords should be referred by law if they violating the health code. Instead of abatement, there are many other methods of keeping children away from lead. For example, just by cleaning the floors properly, limiting access to windows (by placing plants or any sort of obstruction near the windows), cleaning the children's hands from time to time, and making sure there is no dust on the furniture or furnishings that the child comes in contact with.

d. It is very important for health professionals to assess the dietary intake of the children so that they can assess that children do not have iron deficiencies. Health researchers have found that children who are healthy have lower rates of lead poisoning than unhealthy children living under similar risk condition.

3. Awareness Program for the Parents:

Videotapes educating parents on the effects of lead poisoning can provide knowledge to the parents. Parents will be more conscious of this child hazard for which they might have no clue at the present time. Media could play a vital role in making the families aware of this hazard i.e. through advertisements, in cartoons and on children's television channels

4. Provide Coordination between the Health Department and Families at Risk

a. Minority families may have language barriers which might be one of the reasons that they might have a lack of knowledge of lead poisoning. It would be better if there were health workers who could speak Spanish. Bilingual Spanish/English leaflets should be provided so these families can understand the risks associated with specific types of housing.

b. Cultural differences can sometimes be a problem for the public health workers as they work to convince the parents about this harmful asymptomatic disease. It would be easier if there are public health workers from the same ethnic communities who can communicate more easily with the families living at risk housing. Cultural differences are important. For example, among Hispanics there could be sensitive issues like the use of lead glazed pottery, ayurvedic medicine, or liturgia (deodorant) that have a quite high proportion of lead that is harmful for both children and pregnant mothers.

5. Create a Community for Eliminating Lead Poisoning

a. A community of 10 families having EBLL children could be formed who would have meeting bi-weekly to make sure that they are supporting each other to reduce their child's lead by providing necessary measures. There will be one pediatric nurse for each "community" who will supervise the meeting every month to see how they are coping with this hazard.

b. For each community willing to work on the problem, funds from HUD and CLPPP should be provided.

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APPENDIX A

LOCATION QUOTIENT MEASUREMENT

Tracts of Kalamazoo County, Michigan	No. of EBLL	Total pop under 6 yrs	X = Case/Total (472)	Y = Pop /Totpop (21709)	X/Y	Risk
Census Tract 1	12	372	3.51	1.71	2.05	1
Census Tract 2.01	0	93	0.00	0.43	0.00	3
Census Tract 2.02	31	194	9.06	0.89	10.14	1
Census Tract 3	107	603	31.29	2.78	11.26	1
Census Tract 5	33	396	9.65	1.82	5.29	1
Census Tract 6	11	207	3.22	0.95	3.37	1
Census Tract 9	26	234	7.60	1.08	7.05	1
Census Tract 10	50	849	14.62	3.91	3.74	1
Census Tract 11	11	253	3.22	1.17	2.76	1
Census Tract 12	0	249	0.00	1.15	0.00	3
Census Tract 13	3	184	0.88	0.85	1.03	1
Census Tract 14.01	0	390	0.00	1.80	0.00	3
Census Tract 14.02	10	662	2.92	3.05	0.96	2
Census Tract 15.01	4	533	1.17	2.46	0.48	2
Census Tract 15.02	0	276	0.00	1.27	0.00	3
Census Tract 15.03	2	422	0.58	1.94	0.30	2
Census Tract 15.04	0	56	0.00	0.26	0.00	3
Census Tract 15.06	1	341	0.29	1.57	0.19	2
Census Tract 15.07	1	427	0.29	1.97	0.15	2
Census Tract 16.01	4	243	1.17	1.12	1.04	1
Census Tract 16.03	4	174	1.17	0.80	1.46	1
Census Tract 16.04	0	75	0.00	0.35	0.00	3
Census Tract 17.01	1	260	0.29	1.20	0.24	2
Census Tract 17.02	11	359	3.22	1.65	1.94	1
Census Tract 18.01	3	305	0.88	1.40	0.62	2
Census Tract 18.02	1	488	0.29	2.25	0.13	2
Census Tract 18.03	1	211	0.29	0.97	0.30	2
Census Tract 19.02	0	301	0.00	1.39	0.00	3
Census Tract 19.04	0	118	0.00	0.54	0.00	3
Census Tract 19.05	2	553	0.58	2.55	0.23	2

Tracts of Kalamazoo County, Michigan	No. of EBLL	Total pop under 6 yrs	X = Case/Total (472)	Y = Pop /Totpop (21709)	X/Y	Risk
Census Tract 19.06	0	449	0.00	2.07	0.00	3
Census Tract 19.07	0	376	0.00	1.73	0.00	3
Census Tract 20.02	1	303	0.29	1.40	0.21	3
Census Tract 20.03	0	554	0.00	2.55	0.00	3
Census Tract 20.04	0	299	0.00	1.38	0.00	3
Census Tract 20.05	0	618	0.00	2.85	0.00	3
Census Tract 21.01	2	572	0.58	2.63	0.22	2
Census Tract 21.02	3	239	0.88	1.10	0.80	3
Census Tract 22.01	1	205	0.29	0.94	0.31	2
Census Tract 22.02	1	641	0.29	2.95	0.10	2
Census Tract 23	124	422	36.26	1.94	18.65	1
Census Tract 24	1	214	0.29	0.99	0.30	2
Census Tract 25	0	142	0.00	0.65	0.00	3
Census Tract 26.01	1	373	0.29	1.72	0.17	2
Census Tract 27	0	685	0.00	3.16	0.00	3
Census Tract 28.01	0	344	0.00	1.58	0.00	3
Census Tract 28.02	0	402	0.00	1.85	0.00	3
Census Tract 29.01	2	340	0.58	1.57	0.37	2
Census Tract 29.03	5	196	1.46	0.90	1.62	1
Census Tract 29.04	0	557	0.00	2.57	0.00	3
Census Tract 29.05	0	735	0.00	3.39	0.00	3
Census Tract 30.02	1	218	0.29	1.00	0.29	2
Census Tract 30.03	0	463	0.00	2.13	0.00	3
Census Tract 30.04	0	584	0.00	2.69	0.00	3
Census Tract 31.01	0	324	0.00	1.49	0.00	3
Census Tract 31.02	0	149	0.00	0.69	0.00	3
Census Tract 32	0	237	0.00	1.09	0.00	3
Census Tract 33.01	0	291	0.00	1.34	0.00	3
Census Tract 33.02	0	603	0.00	2.78	0.00	3
Census Tract 34	1	346	0.29	1.59	0.18	2

APPENDIX B

INDEPENDENT AND DEPENDENT VARIABLES FROM THE U.S. CENSUS

Tract	% EBLL	% MIN OR	% CHI LD	% FEMA L	AV FM SZ	% OLD HO	% LKP LG	% PO OR	% RE NT	Z-Predi cted	Z Resi dual
2.02	15.98	91.2	15.2	9.8	3.4	24.77	0.00	2.06	0.83	3.72	1.19
3	17.74	88.5	13.4	10.0	3.4	22.29	2.42	5.60	1.05	3.54	2.64
5	8.33	27.4	7.7	4.6	3.0	32.46	0.00	5.29	0.67	1.04	1.95
6	5.31	20.3	4.0	2.2	3.0	32.45	0.53	7.74	0.71	0.72	0.77
9	11.11	48.7	14.5	5.5	3.6	33.19	2.34	2.17	0.66	2.02	1.67
10	5.89	40.8	12.9	5.9	3.4	27.86	1.43	5.17	1.08	1.53	-0.51
11	4.35	32.8	10.9	5.2	3.3	32.24	2.97	1.97	0.98	1.28	-0.94
12	0.00	6.5	8.7	1.1	2.8	26.98	0.00	0.42	2.44	-0.04	-0.92
13	1.63	7.3	9.5	4.9	2.9	17.56	0.00	0.31	2.28	-0.25	0.49
14.01	0.00	30.2	11.3	4.3	3.0	7.67	0.00	1.82	4.13	0.53	-2.07
14.02	1.36	23.4	10.6	4.2	2.9	13.71	0.23	2.53	2.71	0.38	-0.94
15.01	0.75	15.0	13.2	2.3	3.0	6.21	0.38	1.33	6.28	-0.20	-0.15
15.02	0.00	15.9	6.2	1.8	2.7	2.43	0.00	2.18	13.58	-0.25	-0.49
15.03	0.47	13.6	9.1	2.0	2.8	13.50	0.19	2.01	3.20	-0.07	-0.58
15.06	0.29	18.8	6.0	1.7	2.8	1.81	0.30	4.13	20.03	-0.14	-0.54
16.01	1.65	16.2	9.2	4.0	2.7	6.47	0.00	1.15	8.83	-0.14	0.27
16.03	2.30	9.4	9.8	3.1	2.9	24.10	0.00	0.68	1.37	0.01	0.36
17.01	0.38	14.2	8.0	2.4	2.7	11.83	0.00	0.89	3.49	-0.09	-0.59
17.02	3.06	16.3	10.3	4.1	2.9	20.27	0.00	1.78	1.69	0.22	0.40
18.01	0.98	15.7	8.3	2.5	2.8	20.64	0.00	1.32	2.00	0.21	-0.83
18.02	0.20	13.1	10.6	3.8	2.8	13.95	0.32	1.55	2.59	-0.08	-0.72
18.03	0.47	17.4	9.2	3.6	3.1	25.36	0.69	0.69	1.42	0.41	-1.54
19.02	0.00	9.1	8.7	1.9	3.0	6.48	0.00	0.37	7.55	-0.46	-0.08
19.04	0.00	6.0	9.9	2.4	2.9	13.54	0.00	0.26	3.67	-0.41	-0.17
19.05	0.36	9.5	10.3	3.3	3.0	3.94	1.45	0.88	8.78	-0.50	0.23
19.06	0.00	10.9	9.3	2.9	3.0	2.02	0.00	1.30	17.63	-0.49	-0.02
19.07	0.00	12.6	9.2	2.8	3.0	1.10	0.00	0.86	38.36	-0.44	-0.12
20.02	0.00	5.6	8.6	3.0	2.9	3.00	0.33	0.45	16.39	-0.70	0.41
20.03	0.00	14.2	11.8	3.3	3.1	1.31	0.00	0.94	44.89	-0.36	-0.28
20.04	0.00	7.1	7.7	1.7	3.1	1.44	0.00	0.38	46.92	-0.68	0.36
21.01	0.35	4.3	8.4	1.8	3.0	4.09	0.00	0.48	14.13	-0.74	0.69
21.02	0.00	4.3	9.4	1.5	2.9	9.37	0.00	0.33	6.52	-0.60	0.20
22.01	0.49	5.7	8.3	3.2	3.1	21.31	0.66	0.76	1.66	-0.23	-0.25
22.02	0.16	11.1	9.0	2.9	3.0	5.94	0.17	2.12	7.49	-0.38	-0.14
23	0.00	4.3	10.0	1.5	3.1	6.30	0.00	0.68	9.31	-0.68	0.36
24	0.47	3.6	10.8	5.2	3.0	14.69	0.65	0.88	2.36	-0.49	0.27
25	0.00	3.6	8.0	1.6	3.0	10.84	0.60	0.46	4.68	-0.59	0.19

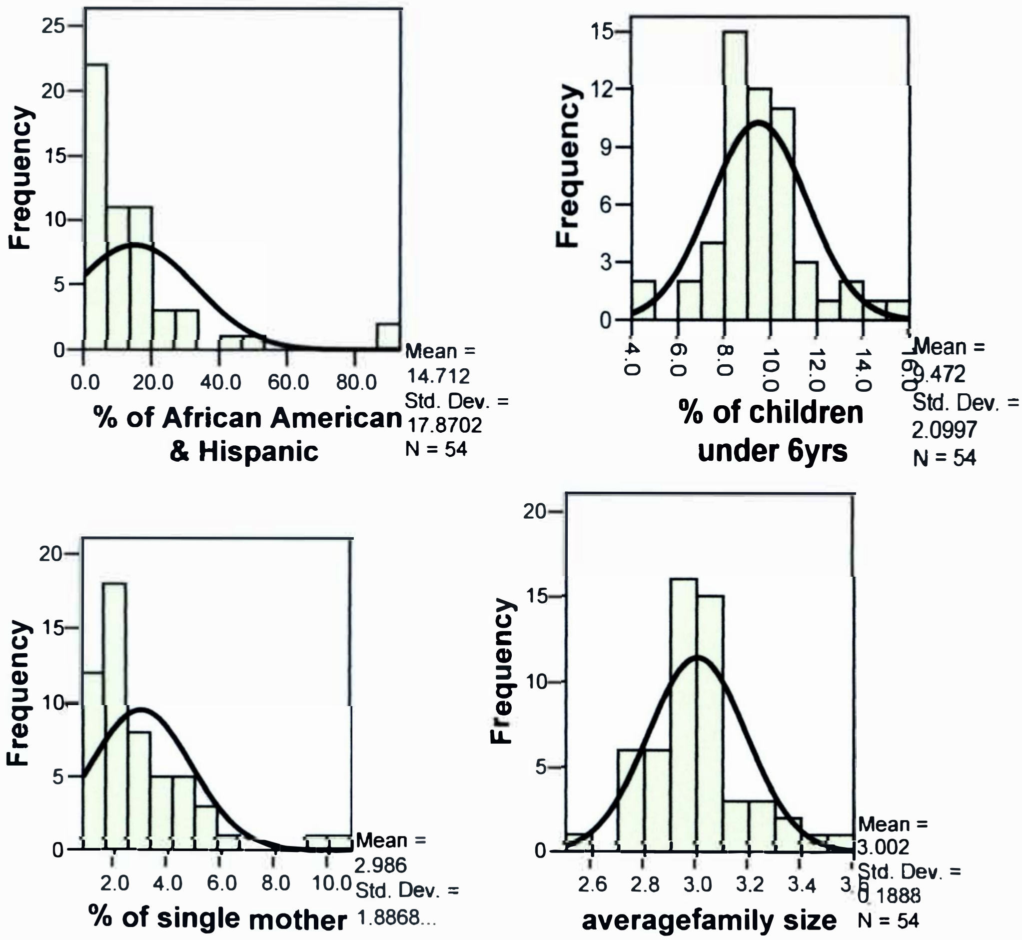
Tract	% EBLL	% MINOR	% CHILD	% FEMAL	AV FM SZ	% OLD HO	% LKP LG	% PO OR	% RENT	Z-Predicted	Z Residual
26.01	0.00	2.6	7.3	1.8	2.9	16.34	0.73	0.58	3.57	-0.50	-0.01
27	0.00	6.6	10.6	2.3	3.0	6.35	0.00	1.14	9.37	-0.57	0.15
28.01	0.00	1.8	9.0	1.7	3.1	7.02	0.00	0.11	7.19	-0.77	0.55
28.02	0.00	5.4	8.2	1.6	3.1	10.63	0.51	1.00	4.21	-0.52	0.04
29.01	0.59	3.4	8.9	1.2	3.1	7.26	0.00	0.71	6.95	-0.69	0.75
29.03	2.55	22.5	4.4	2.1	2.5	1.97	0.00	4.02	12.49	0.03	0.48
29.04	0.00	8.6	8.8	1.3	3.1	4.31	0.26	1.14	16.26	-0.53	0.07
29.05	0.00	16.2	11.9	4.5	2.8	2.16	0.00	3.20	17.22	-0.25	-0.51
30.02	0.46	2.2	10.5	1.0	3.2	5.81	0.57	0.32	11.26	-0.79	0.86
30.03	0.00	4.2	8.7	1.5	3.0	5.71	0.00	0.89	11.05	-0.70	0.40
30.04	0.00	7.1	10.4	.9	3.2	1.46	0.36	0.42	52.36	-0.68	0.36
31.01	0.00	2.6	8.0	1.8	3.0	5.77	0.00	0.62	9.59	-0.77	0.55
31.02	0.00	3.9	9.4	2.3	3.2	18.89	0.16	0.40	2.40	-0.37	-0.26
32	0.00	3.6	10.2	4.4	3.0	20.84	1.10	0.57	2.01	-0.33	-0.33
33.01	0.00	2.3	8.1	1.1	3.1	10.08	0.31	0.34	5.43	-0.67	0.35
33.02	0.00	4.4	10.3	2.3	3.1	8.42	0.00	1.59	5.54	-0.62	0.24
34	0.29	2.4	9.0	1.6	3.1	17.05	0.58	0.77	2.88	-0.49	0.15

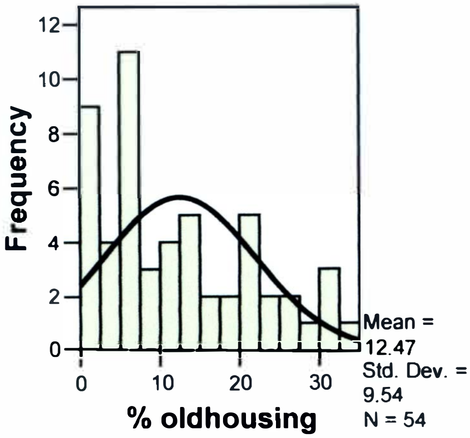
APPENDIX C

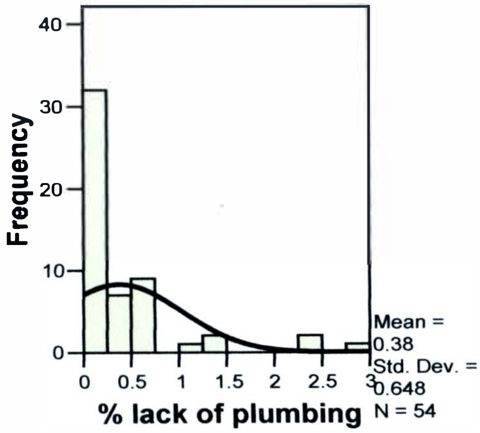
AN OVERVIEW OF THE REGRESSION MODEL

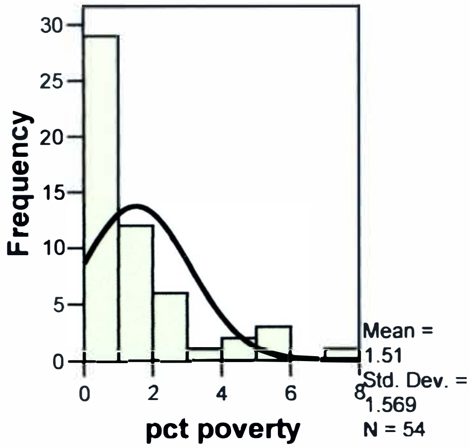
Appendix C1

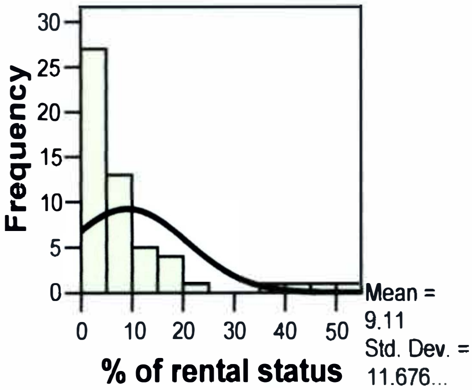
A Set of Histograms of Independent Variables from U.S. Census




Frequency
% oldhousing
Mean = 12.47
Std. Dev. = 9.54
N = 54


Frequency
% lack of plumbing
Mean = 0.38
Std. Dev. = 0.648
N = 54


Frequency
pct poverty
Mean = 1.51
Std. Dev. = 1.569
N = 54


Frequency
% of rental status
Mean = 9.11
Std. Dev. = 11.676...

Appendix C2

Regression Models

First Model:

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.955(a)	.913	.897	1.1927267

a Predictors: (Constant), percentagerental, avfamsz, pct poverty, pctfemale, pct lack plmg, pctoldhous, Pctchildren, Pctminority
b Dependent Variable: pctebll

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	669.565	8	83.696	58.833	.000(a)
	Residual	64.017	45	1.423		
	Total	733.582	53			

a Predictors: (Constant), percentagerental, avfamsz, pct poverty, pctfemale, pct lack plmg, pctoldhous, Pctchildren, Pctminority
b Dependent Variable: pctebll

Coefficients

Mode		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Confidence Interval f		Collinearity Statistic	
		B	Std. Error	Beta			ower Bound	pper Bound	olerance	VIF
1	(Constant)	-12.462	3.721		-3.349	.002	-19.956	-4.967		
	Pctminority	.155	.021	.746	7.402	.000	.113	.198	.191	5.239
	Pctchildren	-.260	.141	-.147	-1.846	.072	-.543	.024	.308	3.252
	pctfemale	.206	.204	.104	1.008	.319	-.205	.618	.181	5.538
	avfamsz	4.337	1.434	.220	3.025	.004	1.449	7.225	.366	2.729
	pctoldhous	.056	.028	.144	2.018	.050	.000	.112	.382	2.620
	pct lack plmg	-.318	.347	-.055	-.917	.364	-1.018	.381	.530	1.887
	pct poverty	.095	.156	.040	.612	.544	-.218	.409	.450	2.222
	percentagere	-.068	.128	-.033	-.533	.597	-.325	.189	.519	1.927

a Dependent Variable: pctebll

Second Model:

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.955[a]	.912	.900	1.1750868

a. Predictors: (Constant), pct lack plmg, Pctchildren, pctoldhous, Pctminority, avfamsz, pctfemale

b. Dependent Variable: pctebll

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	668.683	6	111.447	80.710	.000(a)
	Residual	64.899	47	1.381		
	Total	733.582	53			

a Predictors: (Constant), pct lack plmg, Pctchildren, pctoldhous, Pctminority, avfamsz, pctfemale
b Dependent Variable: pctebll

Coefficients[a]

Mode		Unstandardized Coefficients		tandardize Coefficients			Confidence Interval		llinearity Statisti	
		B	td. Erro	Beta	t	Sig.	wer Boun	pper Boun	oleranc	VIF
1	(Constan	11.464	3.447		-3.326	.002	-18.398	-4.530		
	Pctminor	.161	.018	.772	8.894	.000	.124	.197	.250	4.003
	Pctchildr	-.285	.126	-.161	-2.264	.028	-.538	-.032	.373	2.679
	pctfemal	.214	.201	.108	1.062	.294	-.191	.618	.181	5.524
	avfamsz	4.017	1.333	.204	3.014	.004	1.336	6.699	.412	2.430
	pctoldho	.067	.021	.171	3.129	.003	.024	.110	.627	1.596
	pct lack p	-.280	.339	-.049	-.826	.413	-.961	.402	.541	1.848

a. Dependent Variable: pctebll

Third Model:

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.953[a]	.909	.901	1.1700508

a. Predictors: (Constant), pctoldhous, Pctchildren, Pctminority, avfamsz

b. Dependent Variable: pctebll

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	666.500	4	166.625	121.711	.000[a]
	Residual	67.082	49	1.369		
	Total	733.582	53			

a. Predictors: (Constant), pctoldhous, Pctchildren, Pctminority, avfamsz

b. Dependent Variable: pctebll

Coefficients[a]

Mode		Unstandardized Coefficients		tandardize Coefficients			Confidence Interval		llinearity Statisti	
		B	td. Erro	Beta	t	Sig.	wer Boun	pper Boun	olerance	VIF
1	(Consta	-9.521	2.976		-3.200	.002	-15.500	-3.541		
	Pctmino	.174	.012	.837	15.122	.000	.151	.197	.610	1.640
	Pctchild	-.213	.107	-.120	-1.987	.053	-.427	.002	.512	1.953
	avfamsz	3.243	1.159	.165	2.799	.007	.915	5.571	.540	1.852
	pctoldho	.069	.019	.178	3.606	.001	.031	.108	.768	1.302

a. Dependent Variable: pctebll

Fourth Model:

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.945(a)	.893	.889	1.2386110

a Predictors: (Constant), pctoldhous, Pctminority
b Dependent Variable: pctebll

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	655.340	2	327.670	213.583	.000(a)
	Residual	78.242	51	1.534		
	Total	733.582	53			

a Predictors: (Constant), pctoldhous, Pctminority
b Dependent Variable: pctebll

Coefficients[a]

Mode		Unstandardized Coefficients		tandardize Coefficients	t	Sig.	Confidence Interval		llinearity Statisti	
		B	td. Erro	Beta			ower Bour	pper Bour	oleranc	VIF
1	(Consta	-1.952	.283		-6.892	.000	-2.521	-1.384		
	Pctminc	.174	.011	.835	16.463	.000	.153	.195	.813	1.229
	pctoldhc	.082	.020	.211	4.157	.000	.043	.122	.813	1.229

a Dependent Variable: pctebll