Superfund Sites and Cancer: Association or Causation

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ABSTRACT

Approximately 11 million Americans live within one mile of a Superfund site that may be contaminated with hazardous chemicals that include: aroclor, lead and benzene. These chemicals along with a host of others can cause cancer, which is rapid, out of control cell growth. GIS and statistical analysis were used to assess the spread of these chemicals, and their relation to cancer. Environmental Protection Agency (EPA) provided superfund site data was used to map the location of superfund sites. Centers for Disease Control (CDC) county-wide, site-specific cancer incidence rates for the years of 1998-2002 were used to analyze any cancer trends. Within EPA Region 5 (Illinois, Wisconsin, Minnesota, Michigan, Indiana and Ohio), three sites were selected that had similar topography, site age, and location to waterway. Five invasive cancer types were focused on, they include: lung/bronchus, breast, colorectal, prostate and leukemia/lymphoma. There were no consistent trends associated with chemicals and cancer. More definitive studies are needed to properly assess the spread of these chemicals and their effects on individual communities.

BACKGROUND

Roughly one-fourth of all people in the United States live within four miles of a highly polluted toxic waste site and between three and four million of these people are children under the age of 18 (Landrigan, 1997). Masses of potentially harmful chemicals reside within these a government specified Superfund sites-including aroclor, benzene and lead, which are known to be human carcinogens. Several factors contribute to cancer development, but hazardous chemicals can make it effortless for cancer cells to proliferate. Since, Superfund sites house many cancer causing chemicals one can hypothesize the two are directly correlated. The purpose of this paper is to explore Superfund sites and their link to cancer within county populations.

Superfund sites have been a problem for decades but were not given the proper attention until 1980. In 1980, the Environmental Protection Agency (EPA) passed the Environmental Response, Compensation, and

Liability Act (CERCLA) that is popularly called Superfund. The act was later adjusted in 1984 by the Superfund Amendments and Reauthorization Act (SARA). Both CERCLA and SARA are "aimed at rapid containment, cleanup, or remediation of abandoned toxic waste sites" (Cunningham, 2004). Under CERCLA, the EPA is authorized to commence clean up of a site when toxic materials found in the site are already seeping into the environment, at which time, the liable groups, site owners, waste producer and transporters are legally responsible for cost recovery (Cunningham, 2004). Additionally, under SARA, the people of the community where the site is present have the legal right to know where Superfund sites are and what chemicals reside within them. CERCLA also called for the EPA to release a list of the most contaminated sites, this list is known as the National Priorities List (NPL), as well as to put in place parameters for making the Superfund program feasible (Heil, 1986). For a site to be placed on the NPL it must pose some form of human risk. Appendix 1 shows a detailed map of every NPL site in the United States. From old factories and landfills to mining sites and private dumps, superfund sites appear in many different forms. Many of these sites qualify because they are known to be leaking chemicals into the surrounding area.

Health hazards

As previously stated, superfund sites can be found all over the United States and these sites contain carcinogenic chemicals. Cancer caused by carcinogenic compounds, is the rapid, out-of-control cell growth that results in malignant tumors (Cunningham, 2004). "*In vitro* experiments have shown that chemicals in the environment can cause genetic damage, modulate cell proliferation (cause cancer), bind to hormone receptors, and regulate

enzyme activity" (Wolff, 1997). The knowledge of carcinogenic toxins within close proximity of a household, school building, playground, lake, or water source should be enough to concern even the most diehard anti-environmentalist. The amount and type of carcinogenic toxins present can help to estimate the type of cancer strains that may be present at a given site, but this does not matter unless you take into account what kind of chemicals are present.

These chemicals can be classified in two ways: water soluble or fat soluble. Water soluble chemicals disband easily in water; where as fat soluble chemicals simply dissolve in oil (Campbell, 2004). The fat soluble substances are not mobile on their own and thus need some form of transport. As soon as they enter the body, fat soluble chemicals can cause severe problems. "Once inside the cells, oil (fat)-soluble materials are likely to accumulate and to be stored in lipid deposits, where they may be protected from metabolic breakdown and persist for many years" (Cunningham, 2004). Whereas, water soluble substances cause problems within the body because the toxins have an 'open door' to most cells because said cells are already immersed in a liquid solution (Cunningham, 2004). On the other hand, wind borne toxins are introduced directly into our lungs and other cells and tissues. With this known, there is no doubt that from these sites stems the potential for human health problems. "The health hazards of these sites range from such minor discomforts as headaches and nausea to possibly life-threatening ailments such as cancer and birth defects that may not manifest themselves for years"(Heil, 1986).

Chemical movement through the environment

At Superfund sites hazardous chemicals seep into the ground, infiltrate into the water, and are carried by the wind. Each of these

environmental spheres can worsen the spread of any chemicals that may be present at a site. The ground we walk upon is very important to our daily lives, soil is used for crop production, timber production, and grazing land to name a few. The delicate soil composition can be completely altered by the introduction of foreign chemical substances. Soil is not motile. Unless a chemical is in some kind of liquid form it can not move throughout the soil, so it sits and accumulates. This can cause problems because there may be more than one chemical accumulating atop another.

Water soluble toxins can also have acute effects. Water is liquid and liquid moves; it fills in where it can and takes up space. Consequently, when it rains or snows, the water that does not contribute to runoff or is not evaporated out, infiltrates through the soil. Whatever water is not trapped within the air spaces in the soil trickles down into the groundwater. According to Cunningham (2004), one of our more important resources for freshwater is groundwater. Since most, if not all, life on earth revolves around water, it is safe to assume that one would not want to consume or use contaminated fresh water. On the other hand, wind spread toxins pose a totally different threat. “We breathe far more air every day than the volume of food we eat or water we drink” (Cunningham, 2004).

Since it is clear how chemicals can move from the environment to our bodies, it is necessary to concentrate on the substances that will be focused on in this paper: aroclor, lead and benzene. Each of these key toxins contributes to a different type of health difficulty. These contaminants may be carcinogenic (causes cancer), teratogenic (causes embryonic abnormalities) or mutagenic (causes alterations in genetic material). One of the other most important things to know about a carcinogenic chemical is whether or not it is an initiator or a promoter. An initiator is the chemical

from which the cancer originates whereas; the promoter is the chemical that triggers the rapid, out of control cell growth (Wolff, 1997). Furthermore, all three of these toxins can be found in the EPA's top 20 toxic and hazardous substances (Appendix 2).

Aroclor

Aroclor is a commonly used additive in pesticides and herbicides, and is generally used in commercial farming and landscaping (Appendix 3). It is a fat soluble teratogen and carcinogen, and once in the environment, aroclor can move through all three environmental mediums (air, water, and soil). It can enter the air through evaporation and then be transported over long distances both as a vapor and in the form of solid particles (Ernst, 1996). Aroclor can remain securely in the soil because it does not easily break down in soil; it can be present for multiple months or years. If aroclor is found in water it can stick to sediments or evaporate into the air. When aroclor is in its gas phase it causes the most damage, this is where aroclor can readily accumulate in tissues and fats (Ernst, 2006). Aroclor is an initiator, because the presence of many cancers depend on the presence of aroclor in the system.

Lead

Lead is a commonly occurring natural metal, and can be found in many different vicinities including the soil, and water. The metal is used largely in manufacturing of circuit boards and lead based paint as well as piping for plumbing and gasoline (Appendix 3). Lead may be released to water by natural weathering processes, by discharge from industrial facilities or by leaching from landfills or soil. Contact to lead can result

from consumption of food, drinking water, or incidental ingestion of soil or dust contaminated with lead. Most drinking water contains only very low levels of lead and is usually not an important site of exposure, although lead may be leached from plumbing fixtures (CDC, 2005). Lead is a toxic metal, more specifically; it is a neurotoxin and a carcinogen. According to Cunningham, "approximately 20 percent of all inner city children suffer some degree of developmental retardation from high environmental lead levels" (2004). Because lead on its own is not a threat, it is a promoter.

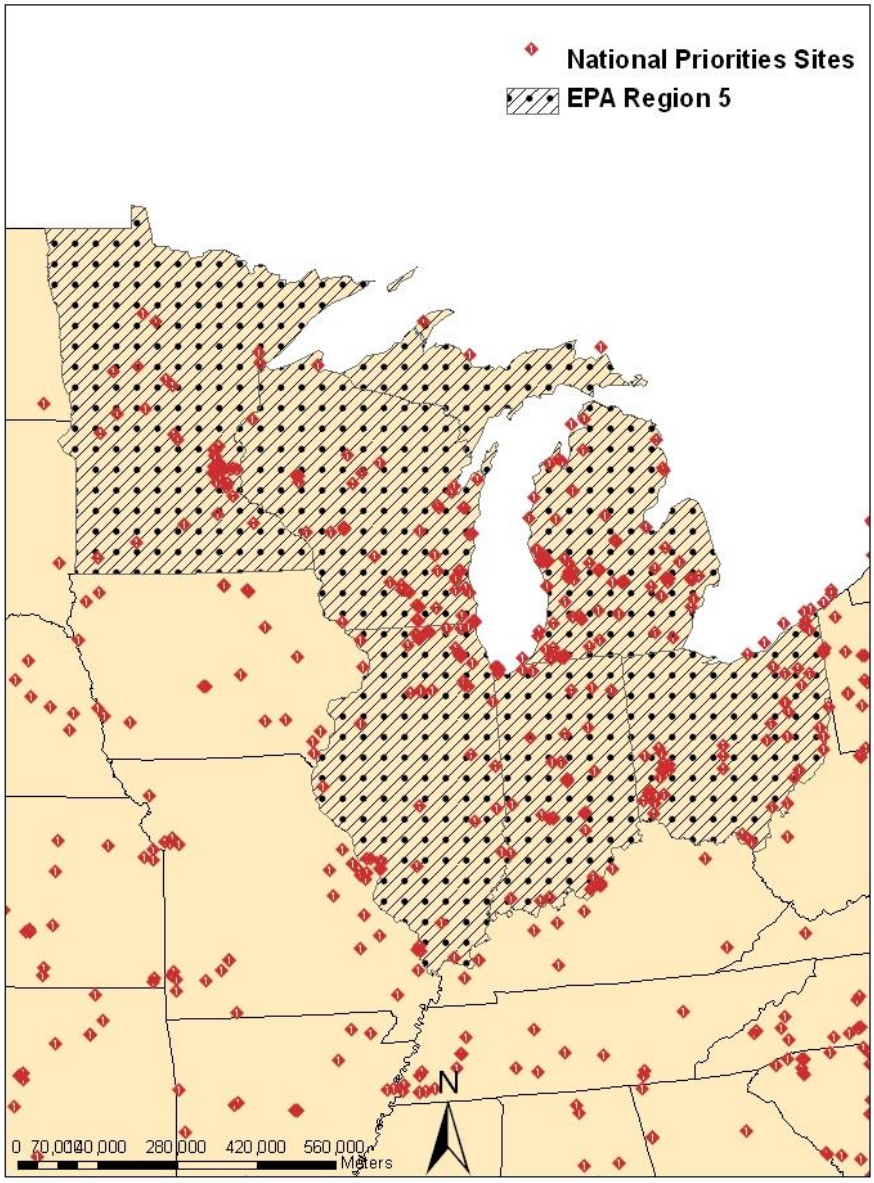
Benzene

Benzene is found in many different industries including, pesticide manufacturing, cleaning solvents and furniture varnish solvents (Appendix 3). It, also a fat-soluble chemical, is generally found in a liquid form. According to the Center for Disease Control (CDC), benzene is a colorless liquid at room temperature that evaporates into the air very quickly (CDC, 2005). The vapor is normally heavier than the surrounding air and it sinks into low-lying areas. Benzene contamination was a problem in Clinton County, Pennsylvania for many years.

METHODS

In performing the research, information was gathered primarily from the Environmental Protection Agency (EPA), the Centers for Disease Control (CDC), the National Cancer Institute (NCI) as well as state cancer registries. The federal government has divided the country into 10 superfund regions (Appendix 4). The region being focused on in this paper is region 5, which is located in the Midwest and includes sites in Illinois, Wisconsin, Minnesota, Michigan, Indiana and Ohio. (Figure 1)

Figure 1: EPA Region 5



The number and the location of superfund sites vary from state to state, but they are generally in light to heavy industrial, and mixed residential areas. The three focus sites are Hagen Farms (Dane County, WI), Sangamo Electric Dump/Crab Orchard National Wildlife Refuge (Williamson County, IL), and Rasmussen's Dump (Livingston County, MI), see table 2.

Table 2: Location, population and land area for the counties of the three chosen sites

Site Name	State	County Name	County Population	County Land Area†	County Land Area Covered in Water†
Sangamo/Refuge	Illinois	Williamson	62,196	1,097	54
Hagen Farm	Wisconsin	Dane	426,526	3,113	94
Rasmussen's Dump	Michigan	Livingston	156,951	1,472	44

† area measured in km2

These sites were chosen because they have roughly the same topography and each site has a waterway(s) within close proximity. All of these sites are roughly the same age, approximately 40 years, which means that the amount of time for seepage of chemicals to have occurred is about the same. Each of these sites exhibited high amounts of contaminants, and it is expected that there will be a correlation between the chemicals in the three Region 5 superfund sites and the incidences of cancer in the surrounding areas by using GIS and various statistical methods.

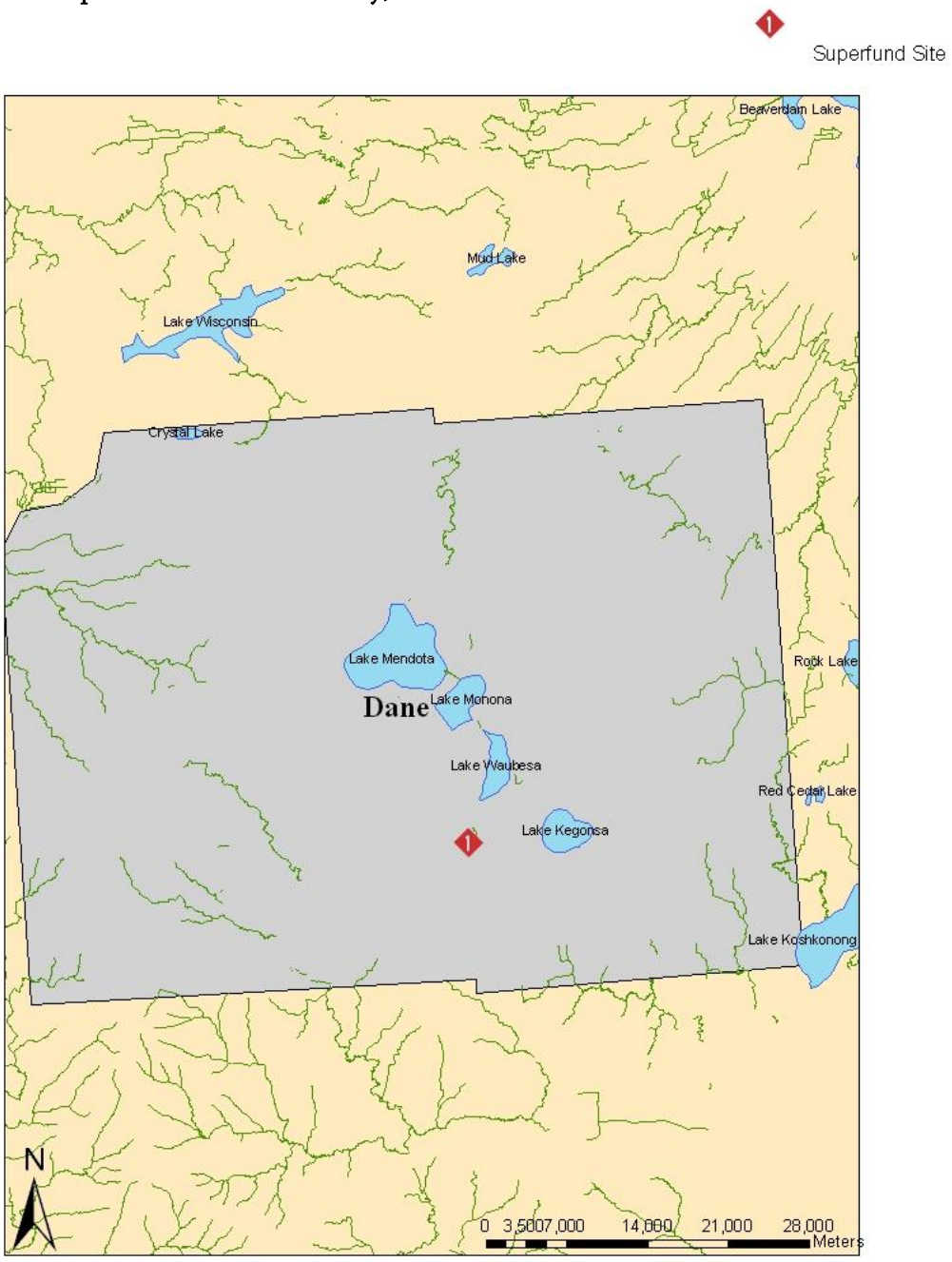
Selected Sites:

Dane County, Wisconsin-Hagen Farm

Hagen Farm is located in the Dunkirk Township, Dane County, Wisconsin. During the 1950s, Hagen Farm was a part of a sand and gravel mining venture, and became an industrial and municipal waste site in the 1960s (Hagen Farm, 2005). The site is located in the watershed of the Yahara River (Hagen Farm, 2005). All of the years of hazardous waste pose a particular threat to the groundwater. “The groundwater table is less than 10 feet from the bottom of the wastes”, and the land slopes toward the Yahara River (Hagen Farm, 2005). In the 1980s, Mr. and Mrs. Hagen, who used the land primarily for grazing sheep, purchased the land. Currently there are six

homes within 1500 feet of the site. Figure 2 displays the area surrounding the site, as well as the waterways.

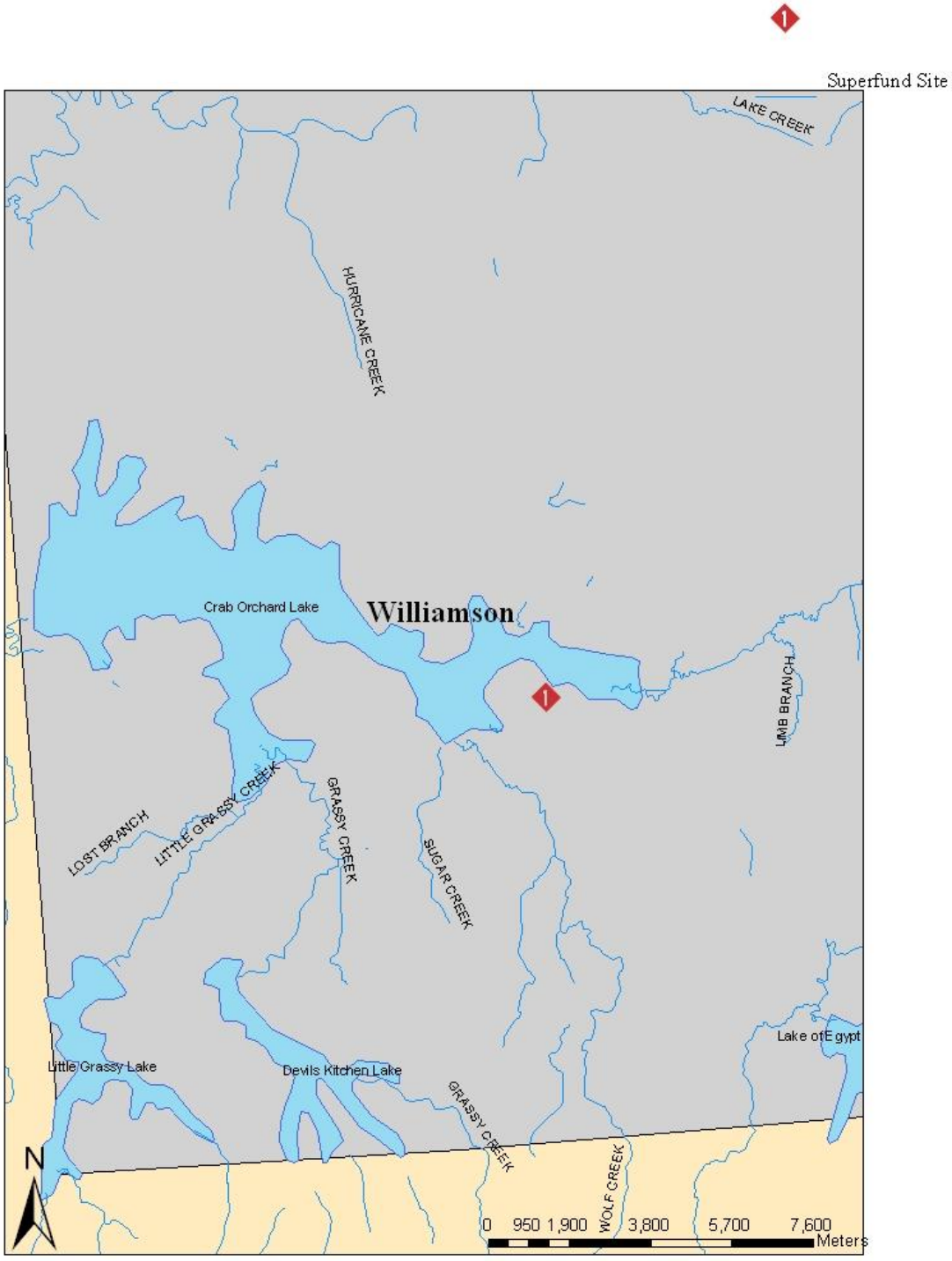
Figure 2: Hagen Farm superfund site in Dane County, Wisconsin



Carterville, Sangamo Electric Dump/Crab Orchard National Wildlife Refuge

Sangamo Electric Dump/Crab Orchard National Wildlife Refuge (the Refuge) was originally farmland that was then used for industrial manufacturing in the 1950s. The Refuge has been used to manufacture munitions, transformers, automobile parts, fiberglass boats, metal parts, electrical components, electroplating, cardboard boxes, and ink (Sangamo, 2005). Since most of this material was disposed on-site, there are high levels of many contaminants, the highest being PCBs or polychlorinated biphenyls. Aroclor is the PCB being focused on in this paper. In fact, high levels of PCBs were found in some of the large bottom-feeding fish (e.g., channel catfish, carp) in Crab Orchard Lake, approximately 100 yards south of the site (Sangamo, 2005). This could mean that the chemicals traveled at the very least 100 yards to the lake. In 1980, Southern Illinois University-Carbondale began to conduct studies of the Refuge and surrounding areas. Currently there are no homes adjacent to the site, but there is a major water body that supplies many people with water and recreation. Figure 3 displays the area surrounding the site, as well as the waterways.

Figure 3: Sangamo Electric Dump site located in Williamson County, Illinois



Brighton, Rasmussen's Dump

Rasmussen's Dump is located in Green Oak Township, Livingston County, Michigan. The site is approximately 1.5 miles northeast of Hamburg, Michigan, and can be found at 9040 Spicer Road in Brighton. The site became an unlicensed dump during the 1950s and began accepting domestic and industrial wastes during the 1960s (Rasmussen's Dump, 2005). In 1972, the landfill became the site of sand and gravel mining. The adjacent property is currently used as housing on the north end, gravel/sand mining on the west, peat mining and livestock grazing to the south (Rasmussen's Dump, 2005). Recently there has been private residential construction across the street from the site and a large sub-division is currently being constructed near the site. Figure 4 displays the area surrounding the site, as well as the waterways.

Figure 4: Rasmussen's Dump site located in Livingston County, Michigan

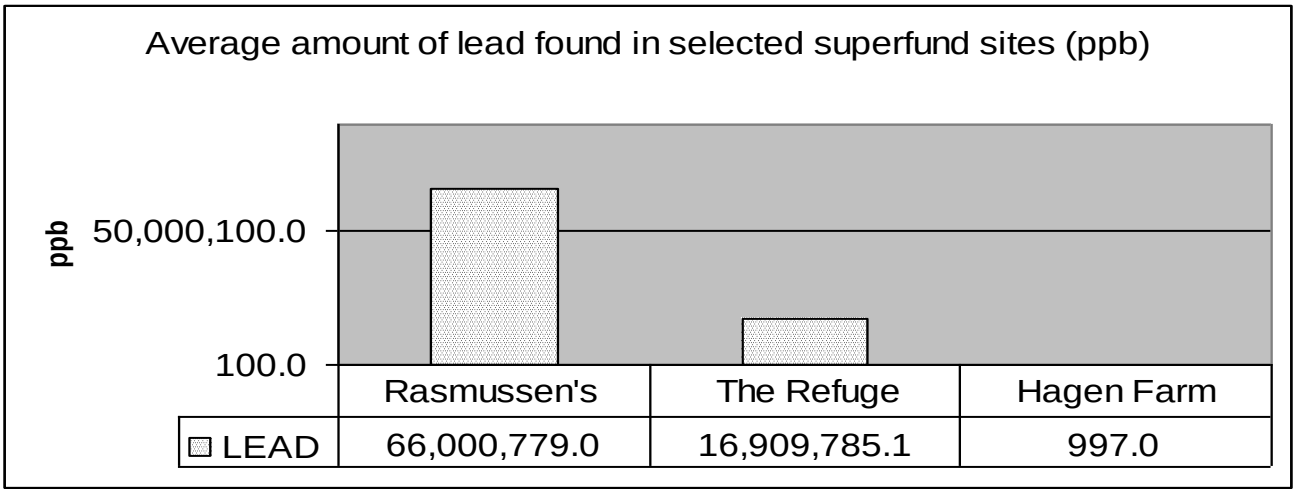
Doctor/Patient privilege made specific city cancer data virtually impossible to obtain because that information can only be given voluntarily. However, county cancer data (without addresses) is readily available from the CDC. Five invasive cancer types were chosen for analysis: breast, colorectal, lung and bronchus, prostate and leukemia/lymphoma. An invasive cancer site is one where cancer has spread beyond the layer of tissue in which it developed and is growing into surrounding, healthy tissues (CDC, 2005). Each of these cancers has been linked previously in studies to the chemicals in question: aroclor, benzene and lead (Wolff, 1997 and Smith 1996). Total amounts for the invasive cancers are for both sexes and all races, and represent the amounts for years 1998-2002. Percentages were found by the subsequent formula: $(n/p)*100$, where **n** represents the total number of people with that cancer type and **p** represents the number of people in the population. In order to obtain accurate percentages from each state, the population and the total number of people with cancer from each Superfund county were subtracted from the total amount for the state: see the following formula. $P_1-P_2=P_1^*$, where P_1 represents the population of the state, and P_2 represents the population of the county containing the targeted Superfund site. P_1^* represents the new adjusted population of the state. $N_1-N_2=N_1^*$, where N_1 represents the total number of people with cancer in the state, and N_2 represents the total number of people with cancer in the county. N_1^* represents the new adjusted total number of people with cancer for the state.

RESULTS

The following are the results for each county and state comparison. It is important to remember that these county wide data may not accurately reflect the experiences of the cities where the sites are, but it helps to show trends where trends may be present.

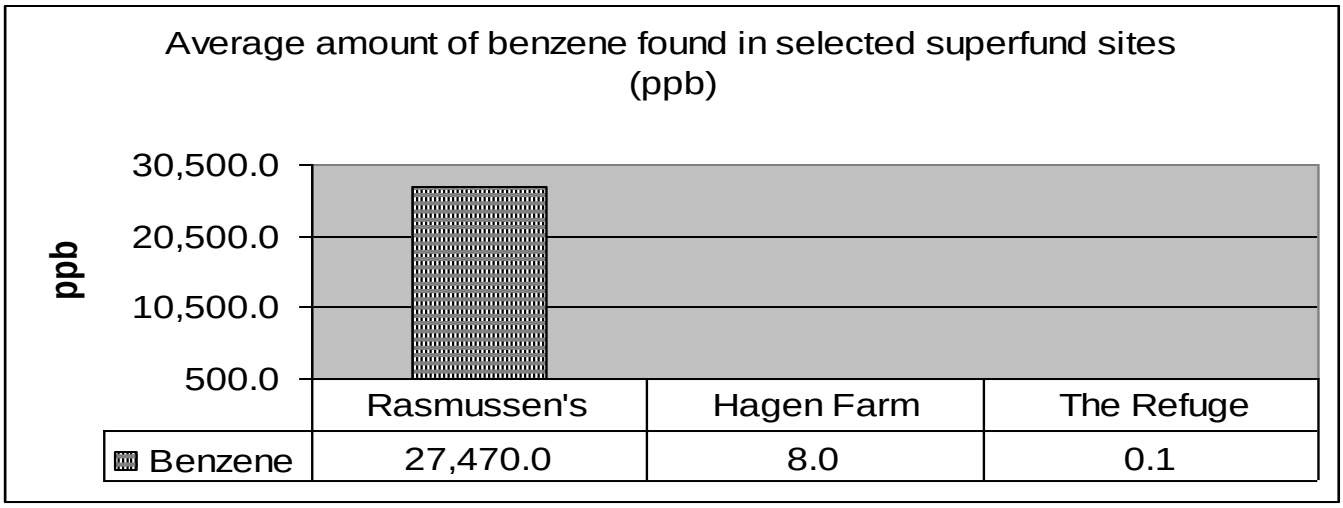
Chemical concentrations for each site were measured in ppb or parts per billion; 1 ppb is equal to 1 µg/kg or microgram/kilogram. The chemical concentrations for lead were all around higher than aroclor or benzene and ranged from 66000779.0 ppb to 997.0 ppb with the highest level at Rasmussen's Dump see Figure 8.

Figure 5: Average lead amount



However, benzene levels were remotely low for all of the sites, ranging from 27470.0 ppb to 0.1 ppb, with the highest amount at Rasmussen's Dump.

Figure 6: Average benzene amounts



The levels for aroclor fell roughly in the middle between lead and benzene, ranging from 36695101.4 ppb to 1.0 ppb, with the highest amount at The Refuge.

Figure 7: Average aroclor amounts

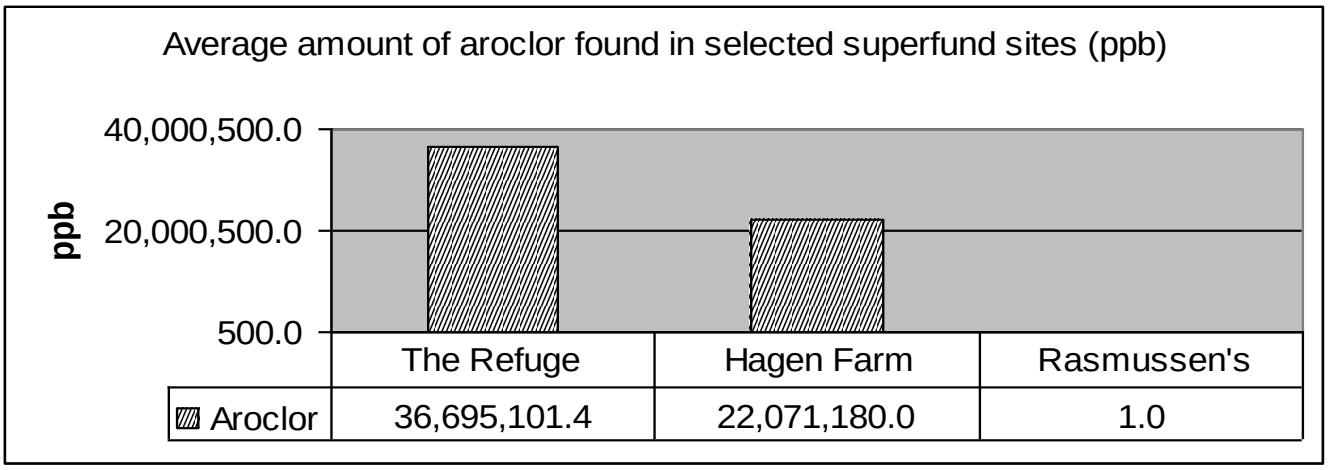


Table 1: Sangamo Electric Dump/Crab Orchard National Wildlife Refuge (Williamson County, Illinois)

Illinois

Cancer Type	Population***	Total # of people with cancer	Percentage Based on Population Size
Breast	12,357,997	44,025	0.356%
Colorectal	12,357,997	35,704	0.289%
Lung and Bronchus	12,357,997	43,150	0.349%
Prostate	12,357,997	41,060	0.332%
Leukemia/Lymphoma	12,357,997	26,442	0.214%

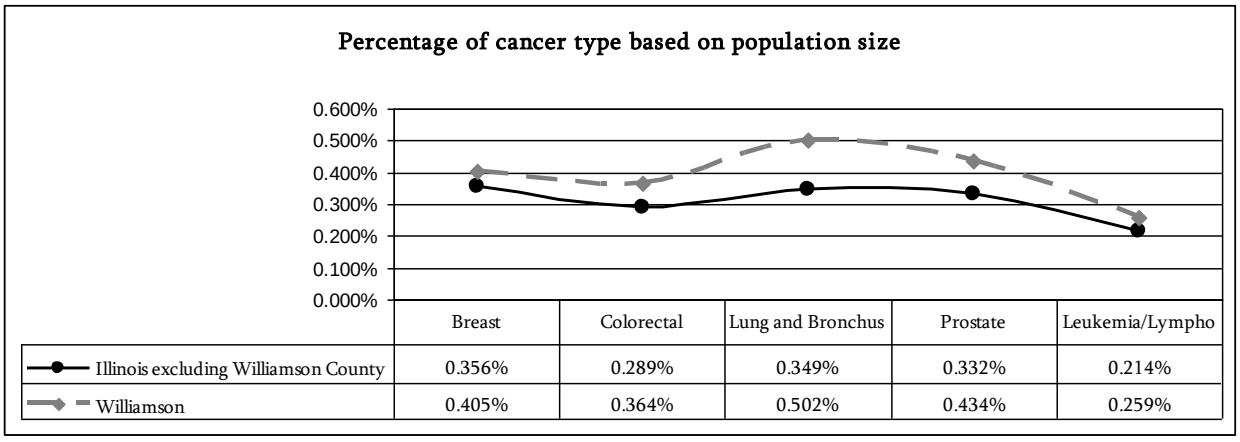
Williamson County

Cancer Type	Population***	Total # of people with cancer	Percentage Based on Population Size
Breast	61,296	248	0.405%
Colorectal	61,296	223	0.364%
Lung and Bronchus	61,296	308	0.502%
Prostate	61,296	266	0.434%
Leukemia/Lymphoma	61,296	159	0.259%

*** State data represented excludes the county in question

Cancer rates appear to be higher in Williamson County when compared to the state as a whole. The state houses 434 superfund sites, whereas eight sites exist within the Williamson County limits. The graph below displays the results from the cancer comparisons (figure 5).

Figure 8: Williamson County vs. Illinois cancer comparison



Clearly, the levels of cancer in the county are much higher than that of the state especially in the case of lung and bronchus cancer. The difference between the county's .502% and the state's .349% is .153%. Whereas, the

levels of breast and leukemia/lymphoma cancer was roughly the same in both areas.

Table 2: Hagen Farm

Wisconsin

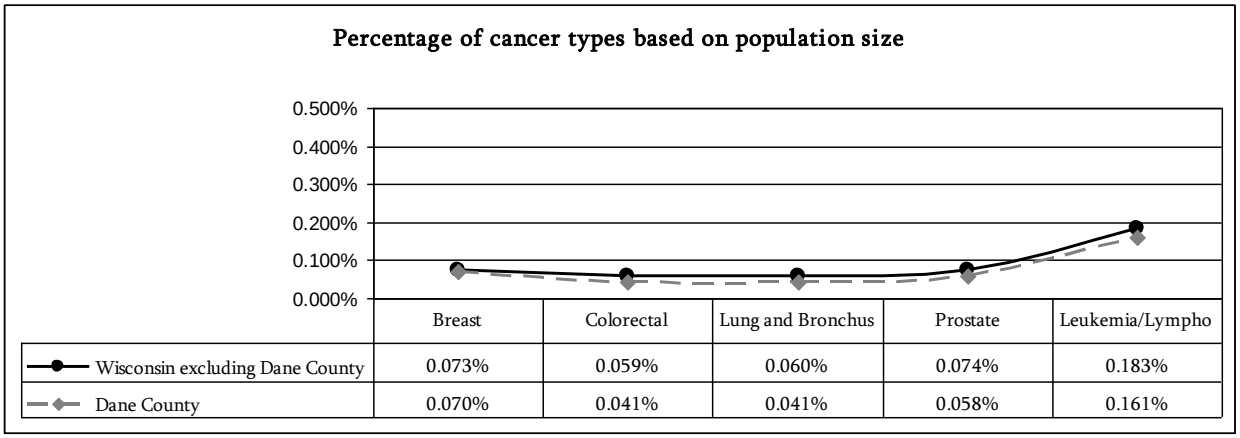
Cancer Type	Population***	Total # of people with cancer	Percentage Based on Population Size
Breast	4,937,149	3,593	0.073%
Colorectal	4,937,149	2,933	0.059%
Lung and Bronchus	4,937,149	2,985	0.060%
Prostate	4,937,149	3,662	0.074%
Leukemia/Lymphoma	4,937,149	9,022	0.183%

Dane County

Cancer Type	Population***	Total # of people with cancer	Percentage Based on Population Size
Breast	426,526	300	0.070%
Colorectal	426,526	177	0.041%
Lung and Bronchus	426,526	175	0.041%
Prostate	426,526	246	0.058%
Leukemia/Lymphoma	426,526	686	0.161%

Based on table 3, values appear to be approximately the same for Wisconsin and Dane County. The percentage for leukemia/lymphoma in the state and county was much higher than any of the other cancer sites. Wisconsin has 159 superfund sites in total while, Dane county has five. Figure 6 displays the differences between the state and county.

Figure 9: Dane County vs. Wisconsin cancer comparison



Overall Wisconsin's cancer rate was higher, but not significantly. Table 4 presents the cancer data for Michigan and Livingston County. Michigan possesses 324 superfund sites whereas, Livingston County houses two.

Table 3: Rasmussen's Dump

Michigan

Cancer Type	Population***	Total # of people with cancer	Percentage Based on Population Size
Breast	9,781,493	35,038	0.358%
Colorectal	9,781,493	27,147	0.278%
Lung and Bronchus	9,781,493	35,863	0.367%
Prostate	9,781,493	42,353	0.433%
Leukemia/Lymphoma	9,781,493	21,268	0.217%

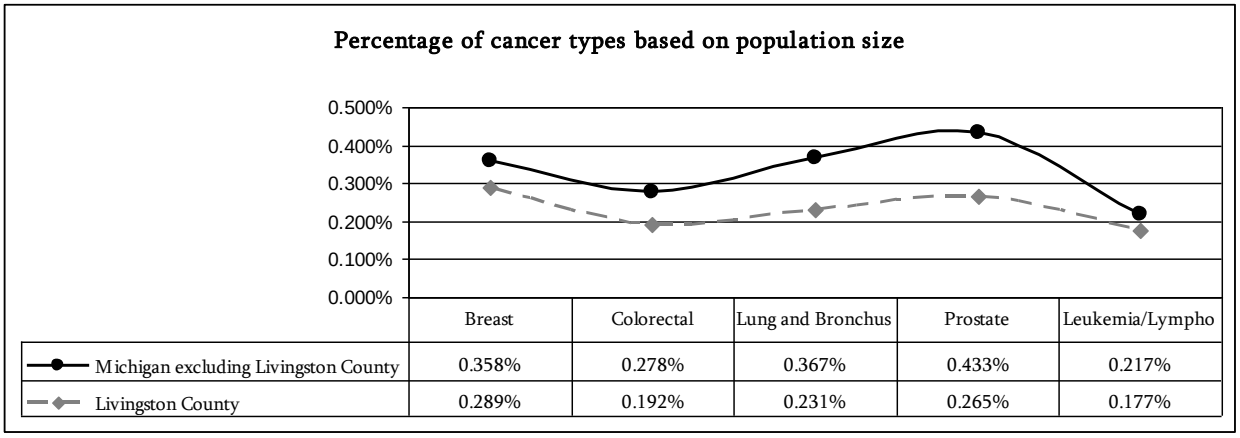
Livingston County

Cancer Type	Population***	Total # of people with cancer	Percentage Based on Population Size
Breast	156,951	453	0.289%
Colorectal	156,951	302	0.192%
Lung and Bronchus	156,951	363	0.231%
Prostate	156,951	416	0.265%
Leukemia/Lymphoma	156,951	278	0.177%

Clearly, the cancer levels are dramatically higher in the state when compared to the county. Each cancer type was significantly higher in Michigan, but prostate cancer held the biggest discrepancy. The state's

percentage was .433 but, the county's percentage was .265 that is a .168% difference. This is plainly shown in figure 7.

Figure 10: Livingston County vs. Michigan cancer comparison



	Breast	Colorectal	Lung and Bronchus	Prostate	Leukemia/Lympho
Michigan excluding Livingston County	0.358%	0.278%	0.367%	0.433%	0.217%
Livingston County	0.289%	0.192%	0.231%	0.265%	0.177%

DISCUSSION

The cancer incidence rates among all races and all sexes were reviewed in Williamson county, Illinois, Dane county, Wisconsin, and Livingston county, Michigan. Although there were individual trends in each place, there were no over all general trends. The Refuge shows the results that were expected, the county's rate is much higher than the state. Unfortunately, Rasmussen's Dump and Hagen Farm did not show the results that had been previously hypothesized. No one particular cancer type was significantly higher in all three groups, thus there was no consistent pattern to indicate a specific chemical as the cause. In addition, there is no information available about other possible cancer inducing indicators such as individual habits, occupation and location in correlation to the site. This does not mean that cancer influxes may not happen in the future, or have not already happened in the past. For example:

"Children are highly vulnerable to carcinogens, and carcinogens encountered in the environment clearly cause cancer in children. Also carcinogenic exposure that occur in childhood can lead to cancer in adult

life, and a recent analysis by the National Research Council found that children can acquire up to 50% of their cumulative lifetime exposure to certain carcinogenic chemicals by the age of 5 years" (Landrigan, 1997).

Also, according to the Agency for Toxic Substances and Disease Registry's public health assessment for Hagen Farm, Mr. Hagen "drank water from the livestock well and had reported developing cysts on his skin as a result" (Hagen Farm, 2005). Therefore, it is completely possible that any cancer 'booms' have happened previously, or have yet to happen.

There are numerous strengths and weaknesses in this study. The most significant setback was trying to obtain the cancer data necessary for mapping in GIS. As previously stated, because of Doctor/Patient privilege cancer data that housed specific addresses is impossible to acquire. Zip codes were given for many of the city data sets, but addresses are needed for the purpose of geocoding. Without specific addresses and only zip codes, the cancer data would have been presented on the map as one point atop another until the only point that would be visible would be the last point added to the map. However, county and state provided cancer data aided in plotting any trends that were present, as well as seeing how far cancers extended away from the site in question. Many individualized factors could not be taken into account such as individual exposure. In addition, gender and/or race specific cancer studies could have been conducted to give a different view of the same data. Furthermore, the chemicals presented their own set of problems; the toxicity of chemicals may vary over time or through transport (Goyer, 1983), this can either reduce or increase the chemical's staying power inside the human body. It is clear that more definitive studies are needed to properly assess the spread of these chemicals and their effects on individual communities.

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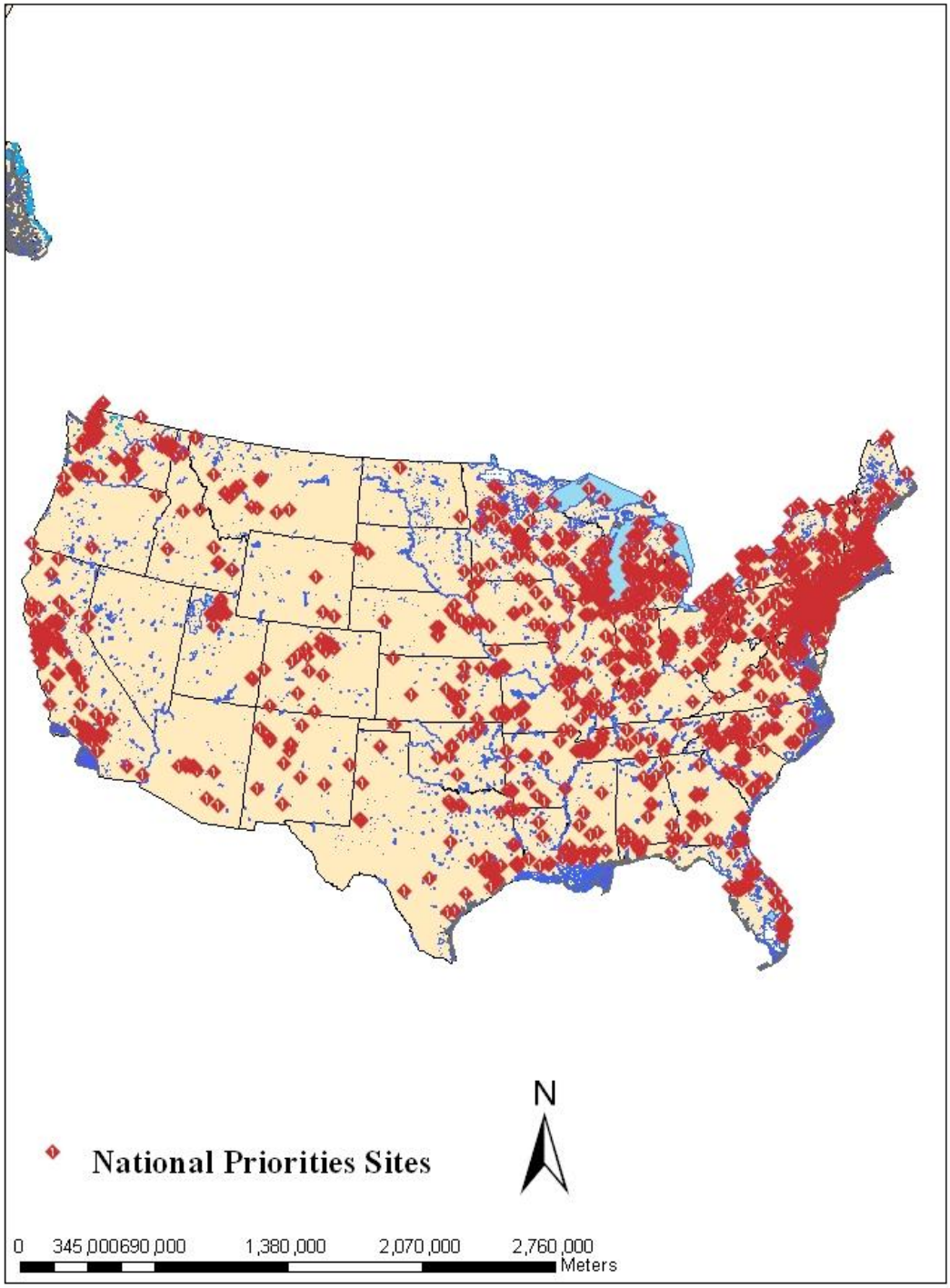
APPENDIX

Appendix 1: Map of all National Priorities Sites in the United States.



Appendix 2: Top 20 Toxic and Hazardous substances

Substance		
Arsenic	**Lead**	Mercury
Polychlorinated biphenyls (PCBs)	Vinyl Chloride	**Benzene**
Cadmium	Benzo(a)pyrene	Polycyclic aromatic hydrocarbons
Chloroform	DDT	**Aroclor 1254**
Aroclor 1260	Trichloroethylene	Dibenz(a,h)antracence
Dieldrin	Chromium, hexavalent	Chlordane
Hexchlorobutadiene		

Appendix 3: Common Uses for Benzene, Aroclor and Lead

Chemical	Industry	Specific Use
Benzene		
	Laboratory Chemicals	Solvents-Dilution
	Pesticide Manufacturing	Solvents-Herbicides
	Pesticide Manufacturing	Solvents-Insecticides
	Pharmaceutical Manufacturing	Solvents-Pharmaceuticals
	Printing	Solvents for equipment cleaning
	Pulp and Paper Manufacturing	Solvents for de-inking paper
	Wood Stains and Varnishes	Varnish Solvents
Aroclor		
	Pesticide Manufacturing	Solvents-Herbicides
	Pesticide Manufacturing	Solvents-Insecticides
Lead		
	Circuit Board Manufacturing	Printed circuit board wire materials
	Fillers	conductive fillers in plastics

Hear Transferring Agents	liquid metal heat-transfer media
Lubricants and Additives	Metals/Inorganic-Solid lubricants
Paints	drying agents
Printed Circuit Board Manufacturing	hot air solder leveling-print circuit board manufacturing
Printed Circuit Board Manufacturing	outer layer etching/plating-print circuit board manufacturing

Appendix 4: Federal Superfund Regions

EPA Superfund Region #	States within that region
Region 1	CT, MA, ME, NH, RI, VT
Region 2	NJ, NY, PR, VI
Region 3	DC, DE, MD, PA, VA, WV
Region 4	AL, FL, GA, KY, MS, NC, SC, TN
Region 5	**IL, IN, MI, MN, OH, WI**
Region 6	AR, LA, NM, OK, TX
Region 7	IA, KS, MO, NE
Region 8	CO, MT, ND, SD, UT, WY
Region 9	AS, AZ, CA, FM, GU, HI, MH, MP, NN, NV, PW, UM
Region 10	AK, ID, OR, WA

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EPA SOURCES

Superfund Information Systems—
http://www.epa.gov/superfund/index.htm

Locate Superfund Sites/Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)—
http://cfpub.epa.gov/supercpad/cursites/srchsites.cfm

CANCER DATA SOURCES

Surveillance Epidemiology and End Results/National Cancer Institute
http://seer.cancer.gov/
Centers for Disease Control and Prevention
http://www.cdc.gov/cancer/npcr/uscs/index.htm

2004 Cancer Burden Data Fact Sheets for each state:
Illinois—
http://www.cdc.gov/cancer/cancerburden/il.htm
Wisconsin—
http://www.cdc.gov/cancer/cancerburden/wi.htm
Michigan—
http://www.cdc.gov/cancer/cancerburden/mi.htm
Ohio
http://www.cdc.gov/cancer/cancerburden/oh.htm