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INVESTIGATION OF CANCER INCIDENCE AND RESIDENCE NEAR 38 LANDFILLS WITH SOIL GAS MIGRATION CONDITIONS: NEW YORK STATE, 1980-1989

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Division of Occupational Health and Environmental Epidemiology
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INVESTIGATION OF CANCER INCIDENCE AND RESIDENCE NEAR 38 LANDFILLS WITH SOIL GAS MIGRATION CONDITIONS: NEW YORK STATE, 1980-1989

EXECUTIVE SUMMARY

Introduction

There is continuing public concern about the incidence of cancer in New York State and the possible role of exposure to toxic substances in the etiology of cancer. The New York State Department of Health receives many inquiries from residents who are concerned that a nearby source of contamination, often a landfill, may have contributed to cancer in their area. Cancer incidence studies for specific landfills are difficult to accomplish, however, because the number of people living near any one site is small and the incidence of potential health outcomes is very low.

Past environmental sampling near several municipal landfills in New York State showed levels of methane gas and volatile organic compounds (VOCs) in soil gas which, if these substances were migrating beyond the landfill boundaries, could be cause for concern. Methane gas is produced during the breakdown of food and garden wastes and other organic matter in landfills. Hazardous VOCs, such as vinyl chloride, trichloroethene, benzene, xylene and toluene, are also present in many landfills as constituents of discarded waste materials. When conditions allow methane gas to migrate through the waste and surrounding soil, hazardous VOCs from the landfill can move with it. Air and soil gases from the surrounding soil can enter buildings through cracks or other openings in the basement or slab. In this way, people residing near off-gassing landfills may be exposed to hazardous components of landfill gas.

This study gathered information on cancer incidence among people residing near the 38 New York State landfills which met the conditions for possible human exposure to hazardous VOCs through the migration of methane soil gas beyond the landfill boundaries. Of the many types of cancer, seven were chosen for this study because they are thought to involve organs and systems most likely to be affected by contact with environmental contaminants. These seven cancers, leukemia, non-Hodgkin's lymphoma, liver, lung, kidney, bladder, and brain cancer, have been linked in some studies with occupational or environmental exposures. The goal of this study was to find out if people residing near off-gassing landfills were more likely than people living elsewhere to be diagnosed with any of these seven cancers.

Methods

The researchers sought information about all known municipal landfills in New York State. They examined detailed information for 245 municipal landfills and found only 38 landfills which should be included in the study. These 38 landfills were chosen because the available information indicated that the production and movement of methane gas could create conditions for possible human exposures to hazardous landfill gas. An area bordering each landfill boundary was identified as the area of potential exposure. This potential exposure area was estimated as a ring or buffer surrounding the landfill. For most landfills this potential exposure area extended 250 feet from the landfill boundary. For five landfills with data that showed further off-site migration of methane gas, larger areas of potential exposure were identified, with a buffer extending 500 feet for four other landfills and 1,000 feet from the landfill boundary for one landfill.

Data from the New York State Cancer Registry were used to find all cases of leukemia, non-Hodgkin's lymphoma, liver, lung, kidney, bladder and brain cancer diagnosed over the ten-year period, 1980 to 1989, among residents of the study area, defined as the zip codes which contained the assumed off-site migration areas for the 38 study landfills. For a comparison group, all non-cancer deaths which occurred in these same years in the same zip codes containing the landfills were also identified from death certificate files maintained by the Department of Health. The residential addresses for each cancer case and each non-cancer death were used to pinpoint the locations of all the cancer cases and all the non-cancer deaths, so that the researchers could see which study subjects resided in the potential exposure areas surrounding the landfills. By comparing the proportion of cancer cases who resided in all the potential exposure areas to the proportion of non-cancer controls residing in all the potential exposure areas, the researchers could evaluate whether living in the potential exposure areas appeared to increase people's risk for each of the seven cancers studied.

Findings

A total of 9,020 cancer cases for the seven types of cancer over the ten year period were found in the study zip codes. Only 49 cancer cases, or fewer than one percent of the study's cancer cases, lived at diagnosis in the off-gassing landfill potential exposure areas. Of the 9,169 deaths sampled from the study area, only 36, again fewer than one percent, were classified as potentially exposed to off-gassing landfills. Epidemiologic studies are usually planned so that the proportion of the study's population which is potentially exposed to the risk factor being evaluated is considerably larger than one percent. The exposure assessment process in this study comprehensively evaluated the existing data on methane sampling in soil and air near the landfills. This process led the researchers to estimate that the size of the area for potential residential exposure to off-gassing from the landfills was smaller than the study researchers had expected when they began planning the study. This relatively small number of people residing in the landfill potential exposure areas is one important finding of this study. The small proportion of study subjects residing in the potential exposure areas results from the estimates, drawn from the available data, that the landfill potential exposure buffer should extend (for all except five of the landfills) 250 feet from the landfill boundary.

Because the study considered all 38 landfill potential exposure areas and study zip codes as a group, it was possible to evaluate whether residence in the potential exposure areas appeared to be related to cancer risk. Each of the seven types of cancer was evaluated separately and analyses were performed separately for males and females. The analyses controlled for age differences between the case and control groups. For each cancer site, separately for males and females, the proportion of cases who lived in the potential exposure areas was compared to the proportion of non-cancer controls who lived in the potential exposure areas. The difference between the proportion of cases living in the landfill potential exposure areas and the proportion of controls living in the potential exposure areas was used to estimate the degree of risk which appeared to be associated with the potential exposure. This risk was expressed in an odds ratio, where a value of 1.00 or less represents no increased risk associated with the exposure, and values greater than 1.00 indicate greater relative risk.

The analyses showed statistically significantly elevated risks for female bladder cancer and female leukemia among women residing in the landfill potential exposure buffers at diagnosis. For female bladder cancer, 1.51 percent of cases lived at diagnosis in the landfill potential exposure areas versus 0.37 percent of the deceased controls. For female leukemia, 1.49 percent of cases lived at diagnosis in the landfill potential exposure areas versus 0.32 percent of the non-cancer controls. For female bladder cancer, the estimate of the odds ratio, or increased risk for people residing in the landfill exposure area, was 4.08; for female leukemia, the increased risk (odds ratio) was estimated to be 4.76. The analyses did not show statistically significantly elevated risks associated with off-gassing landfill potential exposure for male bladder cancer or leukemia, or for the other cancers for males or females, non-Hodgkin's lymphoma, liver, lung, kidney, or brain cancer.

Other social, economic and environmental factors, such as population density, local income levels, and other potential industrial or hazardous waste exposures were then included in the analyses. These factors were included because they could also play a role in the apparent elevation of risk for female bladder cancer and leukemia. When these factors were included, the estimated risk for female bladder cancer and female leukemia for the women living in the landfill potential exposure areas remained statistically significantly elevated and increased in magnitude. Inclusion of these additional factors did not produce statistically significantly elevated estimates of risk for male bladder cancer or leukemia, or for the other cancers in males or females, non-Hodgkin's lymphoma, liver, lung, kidney, or brain cancer.

Conclusions and Recommendations

This study gathered residential information for people diagnosed with cancer and non-cancer deaths in the zip codes which contained thirty-eight off-gassing landfills in New York State. Computerized mapping techniques were used to locate residences and determine whether they were located in the off-gassing landfill potential exposure areas. By combining the residential exposure classification information for all the zip codes and landfills, the researchers were able to evaluate whether cancer risk appeared to be associated with potential residential exposures to VOCs from off-gassing landfills. The study found no statistically significant increase in cancer risk for five sites: liver, lung, kidney, brain, and non-Hodgkin's lymphoma. The study found a statistically significant elevation of cancer risk for bladder cancer and leukemia for females. In this study, cancer risk was estimated to be four times greater for the potentially exposed study subjects than for the presumed non-exposed subjects for both female bladder cancer and leukemia.

This study's findings are limited because there were no data available which measured study subjects' actual exposures. In addition, the study used existing records which did not contain data on other cancer risk factors, such as occupation or smoking habits. Cancer registry and death certificate records provided the address at date of diagnosis or death, but the length of time at the residence was not known. Given these limitations, the very small numbers of exposed cases and controls upon which the findings are based require that caution be used when drawing conclusions from this study. It is important to note as well that if the apparent association between off-gassing landfills and bladder cancer or leukemia is based on a causal relationship, the risk of these cancers attributable to off-gassing landfills in this population, would be very small, less than one percent.

In order to further assess the study findings, the New York State Department of Health will review medical records for the leukemia and bladder cancer cases in females and males that were classified as potentially exposed to off-gassing landfills. In addition, for these two cancer types, city directories will be used to find additional information on length of residence within the off-gassing landfill potential exposure areas for cases and controls. The current status of methane gas monitoring and collection at the study's landfill sites is also being reviewed. If sites are identified in New York State or elsewhere where uncontrolled off-gassing from landfills continues to occur, sampling for off-site contamination through soil gas migration could assess this study's hypothesis about soil migration as a pathway for exposure. If a site with uncontrolled off-gassing and conditions for soil gas migration is identified with people living nearby, homes bordering the site should be sampled to evaluate whether exposures are occurring through soil gas migration. Appropriate preventive actions could then be taken, if necessary, and follow-up of these people in later years could be done to find out if they experience unusual health problems.

After New York State (1973) and the federal government (1976) began regulating landfills, existing open dumps were either closed or upgraded to sanitary landfills, which have a clean fill cover placed on top of the solid waste. Most of this study's landfills (30) began operating before 1970. Many of these older landfills were not lined and capped as they would be if constructed today. By the end of the 1980's only three of the study landfills were still operating, and none remain open today. Methane collection systems began to be installed in the late 1970's to decrease methane migration away from the landfills. Twenty-two of the study landfills currently have methane collection systems and four more are planned to be constructed in 1998.

In 1988 the New York State legislature passed the Solid Waste Management Act which set priorities for solid waste management in New York State. It required New York State communities to develop programs following this ordering of priorities: (1) reducing the generation of waste, (2) reusing and recycling, (3) recovering energy from waste that cannot be recycled, and (4) disposing by land burial or other means approved by NYS Department of Environmental Conservation (DEC). Also in 1988, NYS DEC issued the set of complete rules, known as "Part 360," for constructing, operating and closing landfills. The Part 360 regulations also include rules for monitoring landfill conditions after closure. Since 1988, the number of landfills accepting municipal solid waste in New York State has decreased from about 240 to 30. The landfills remaining tend to be large because the rules for building and running landfills are more strict and this makes the larger ones more economical. Many of the remaining landfills are privately owned; others are owned by cities or counties. They are regulated by NYS DEC, Division of Solid and Hazardous Materials.

All of the study's landfills have been investigated by NYS DOH and NYS DEC as inactive hazardous waste sites. These evaluations address the potential for human health problems related to each landfill site. The actions taken to improve conditions at closed landfills depend on specific characteristics at each site. Remedial actions have included installing systems for collecting landfill gas, capping the landfill, collection of leachate (water run-off) from the landfill, intercepting and treating contaminated groundwater plumes, and continued groundwater monitoring and air monitoring of landfill vents.

This study presents an analysis of the relationship between potential exposure to off-gassing landfills in the 1960's and 1970's and seven types of cancers diagnosed among men and women in the 1980's. Because landfill closures and clean-up activities have changed the conditions at New York State's landfills since the time-frame covered by this cancer study, this study's results do not provide us with information about health risks related to living near landfills today. This study's findings point to the desirability of finding populations with documented exposures to specific chemicals and data on levels of exposure, perhaps by using newly developed biomarker techniques, so that future studies of the health effects of off-gassing landfills might lead to more definitive conclusions.

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ABSTRACT

This study examined whether the risk for seven cancers might be associated with potential residential exposure to VOCs near 38 landfills with soil gas migration conditions in New York State. This record-linkage population-based case-control study utilized New York State Cancer Registry data for complete ascertainment for the years 1980-1989 of male and female liver, lung, bladder, kidney, brain, non-Hodgkin's lymphoma and leukemia incident cases in 38 geographic areas (defined by zip codes) containing these landfills. Controls were randomly selected from all non-cancer deaths in these zip codes for the same time period, frequency-matched to cases by sex and ten-year age group for each cancer. Cases and controls were classified as having potential residential exposure to VOCs from off-gassing landfills based on their residence at diagnosis or death within a potential exposure area which in most cases extended 250 feet from the landfill boundary.

From 245 landfills identified in the state, 38 were selected by means of a thorough evaluation of existing data as likely to be off-gassing methane and thereby potentially exposing nearby residents to hazardous VOCs through soil gas. Of 9,020 total cancer cases for all sites, 49 cases (0.54%) were classified as potentially exposed, and of the total 9,169 controls, 36 (0.39%) were classified as potentially exposed. No statistically significant elevation in cancer risk was found for five sites: liver, lung, kidney, brain, and non-Hodgkin's lymphoma. A statistically significant elevation of cancer risk was shown for bladder cancer in females (OR=4.08, CI 1.36 - 12.21) and leukemia in females (OR 4.76, CI= 1.37 - 16.53). Bladder cancer in males (OR=1.18, CI=0.39 - 3.53) and leukemia in males (OR=1.87, CI=0.59 - 6.00) were elevated but not significantly.

In multiple logistic regression models which included demographic and other environmental variables, the adjusted odds ratios for potential exposure to off-gassing landfills remained statistically non-significant for liver, lung, kidney, brain, and non-Hodgkin's lymphoma among males and females. The adjusted odds ratios for potential exposure for bladder cancer in females (OR=5.52, CI 1.67-18.2) and leukemia in females (OR=5.13, CI=1.45-18.1) increased and remained statistically significantly elevated. The adjusted odds ratios for bladder cancer in males (OR=1.30, CI=0.42-3.97) and leukemia in males (OR=2.16, CI=0.65-7.14) increased but remained statistically non-significantly elevated. For a more distant potential exposure area, extending 500 feet beyond the first potential exposure area, no odds ratios were significantly high or low.

This study found that fewer than one percent of the study subjects residing in zip codes near off-gassing landfills lived close enough to the landfills to be classified as potentially exposed to hazardous emissions. This means that if the association shown in this study between off-gassing landfills and bladder cancer or leukemia is truly based on a causal relationship, overall population risk for these cancers which might be attributable to residence near off-gassing landfills is relatively small. However, for those living in close proximity to such sites (within 250 feet of a landfill boundary), the study findings suggest that there may be an increased risk for

bladder cancer and leukemia in females. This finding must be interpreted in light of the study's limitations, however. Data were not available to confirm whether any exposures to hazardous substances occurred among the study subjects. Information on length of residence (length of potential exposure) or contaminants, or other risk factors such as smoking were not available. Given these limitations, the very small numbers of exposed cases and controls upon which the findings are based require that caution be used when drawing conclusions from this study.

1.0 INTRODUCTION

This report summarizes a study which investigated whether residence near landfills with soil gas migration conditions was associated with the risk of developing cancer in seven sites, liver, lung, kidney, bladder, brain, non-Hodgkin's lymphoma, and leukemia. Past environmental sampling at several municipal landfills in New York State indicated the presence of volatile organic compounds. In a 1987 NYSDOH cancer incidence study of census tracts around a large off-gassing municipal landfill on Long Island, New York, an excess of brain cancer among males and leukemia among females was noted. (1) A 1988 follow-up study confirmed the excess of brain cancer among males, but did not find an excess of leukemia among females, in the census tracts closest to the landfill. The high incidence of brain cancer could not be explained by occupational exposures, but some of the cases were found to have other risk factors for brain cancer. The cases generally lived more than one-half mile from the landfill, however. (2)

There is continuing public concern about the incidence of cancer in New York State and the possible role of exposure to toxic substances in the etiology of cancer. NYSDOH receives many inquiries from residents who are concerned that a nearby source of contamination, often a landfill, may have contributed to cancer in their area. Cancer incidence studies for specific landfills are difficult to accomplish, however, because the number of people living near any one site is small and the incidence of potential outcomes is very low.

For these reasons, this population-based case-control study combined cancer incidence data for a ten-year period from the geographic areas surrounding 38 landfills in New York State. The landfills selected for inclusion in the study are a subset of the state's registry of inactive hazardous waste sites. The cancer cases were identified from the New York State Cancer Registry and the controls are a sample drawn from death certificates.

2.0 BACKGROUND

The hypothesis underlying this study is that hazardous volatile organic compounds (VOCs) might be released from wastes in a landfill in sufficient quantities to increase the incidence of cancer in residents living near the sites. Landfills with soil gas migration conditions are evaluated because methane emissions may carry hazardous VOCs through soil into residential basements. If sufficient quantities of such compounds were released, the level of exposure for nearby residents would depend on a variety of factors in addition to the location of homes in relation to the landfill. These include the nature of the wastes and how they were landfilled; construction of the landfill liner, drainage system and cap; the nature of the soils in the area; rainfall and local meteorology.

Environmental sampling results from municipal waste landfills in New York State indicate the presence of VOCs including vinyl chloride, trichloroethene, benzene, xylene and toluene in air, water and soil around some landfills. (3) Movement of methane produced from decomposition of waste material may transfer these toxins out of the landfill, creating potential for human residential exposures. VOCs are present in landfills as constituents of discarded waste and as the result of degradation or reaction of discarded wastes. Pohland reported in a summary table for an unspecified number of landfills with gas collection and treatment systems a benzene average level of 1.7 and maximum level of 23 ppm (parts per million by volume) in landfill gas collection system inlets. Average reported levels for dichloromethane were 0.9 ppm, for tetrachloroethene, 1.3 ppm, and for trichloroethene, 0.8 ppm at the gas collection inlet. The maximum reported levels for dichloromethane were 12.0 ppm, for tetrachloroethene, 35.0 ppm, for trichloroethene, 8.1 ppm.(4) Whether levels of this magnitude or any level of VOCs from off-gassing landfills reached residents living near the 38 sites included in the present study is not known. Data on whether methane or VOCs are present in residences, and if so, at what level, are generally not available. In this study, residential proximity to off-gassing landfills is used as the indicator of potential exposure to VOCs. There was no actual measurement of personal exposure to VOCs due to off-gassing landfills.

2.1 Methane Gas Production and Migration from Landfills

Methane is produced during the breakdown of food and garden wastes and other organic matter in landfills. This breakdown is an anaerobic microbial process that begins after adequate moisture has accumulated in the waste and other conditions are suitable for transition from the initial aerobic state to the anaerobic digestion process which continues until the readily available organic constituents are stabilized, which is generally several years. The time interval before methane production and the duration of the methane production phase are determined by physical, chemical and microbiological conditions within the waste. Since landfilling is usually done in cells, the location and timing of methane production will be different for the different cells of a landfill. During active methane production, methane and carbon dioxide make up nearly 100% of landfill gases.

After gaseous compounds are released in the buried waste, they migrate to the surface, or to gas collection systems, via molecular diffusion and convection. Convection is transport of the VOC in a moving stream of other gases, analogous to transport of a puff of smoke in the wind. Diffusion, on the other hand, is driven by the difference in concentration of a compound between two locations; migration by diffusion is generally much slower than migration by convection.

Subsurface VOC migration by convection occurs when a pressure gradient exists among the gases within the interconnected pore space in the waste and surrounding soil. The main sources of pressure gradients are underground gas production and active removal of air at a surface or sub-surface location. The most common source of subsurface gas production is methane and carbon dioxide generation by anaerobic decomposition of the waste. The most common sources of air removal systems which generate low pressure regions are landfill gas removal systems with pumps or fans, and buildings. Buildings create regions of lower air pressure which draw air and soil gases from the surrounding soil by the "chimney" effect and by hot air furnace fans or ventilating system exhaust fans. The chimney effect is produced when the air in a building is heated to above the ambient temperature. If there are cracks or openings in the upper parts of the building through which air can escape, the warmer air in the building rises and escapes, reducing the pressure in the basement and first floor to below that in the outside air or soil. If there are cracks or other openings in the basement (or the slab of a house with no basement), soil gas can be drawn in. Building exhaust fans and furnaces that draw air from inside the house can also reduce the indoor air pressure and promote infiltration of soil gases.

Some residents of the area around a landfill may have direct penetration of landfill gases into their homes through soil gas migration. Residents near a landfill may also be exposed to landfill gases through emissions to the ambient air in their neighborhood, outdoors or after it enters their homes. Gases emitted from the surface of a landfill, which are not collected and treated, such as by flaring or using the methane for fuel, are dispersed into the ambient air.

2.2 Potentially Environmentally Sensitive Cancer Sites

In Causes of Cancer, Doll and Peto listed cancer sites that are "not known to be produced by occupational hazards", "that possibly may be produced by occupational hazards" and "cancers that can definitely can be produced by occupational hazards." (5) The seven sites identified for this study are in the latter categories. Additionally, the biologic functions of the liver, lung, kidney, bladder, blood and lymph put these organs and systems at particular risk for direct contact and concentration of substances foreign to the body.

2.2.1 Liver (ICD-9: 155)

Animal studies have shown that there are both natural and synthetic chemicals that elicit hepato-carcinogenesis. Among the synthetics are vinyl chloride, chloroform, and carbon tetrachloride. (6) Due to the enzymatic activity in the liver, biotransformation and bioactivation make this organ especially vulnerable to chemically induced injury and carcinogenic cellular change. (7)

2.2.2 Lung (ICD-9: 162)

Many types of environmental insults have been implicated in increased incidence of lung cancer. Various occupational exposures including asbestos, metal fumes, and polycyclic aromatic hydrocarbons (8), as well as exposures to ambient air pollution (9, 10), and smoking (11), have been shown to contribute to lung cancer. The particular sensitivity of the lung makes it a logical anatomical site in a study of health effects of air-borne contaminants.

2.2.3 Bladder (ICD-9: 188)

Bladder cancer has been associated with aromatic amine manufacturing and the analgesic drug phenacetin. (12) Occupations thought to be at increased risk for development of bladder cancer include painters, hair dressers, chemical, textile, leather and metal workers. Workers in these varied occupations often contact dyes and solvents in their daily activities. Specific aromatic amines associated in occupational studies with bladder cancer include 2-naphthylamine, benzidine, 4-aminobyphenyl, 4,4'-methylene-dianiline, and 4-chloro-*o*-toluidine. (13-14)

2.2.4 Kidney (ICD-9: 189)

The causes of human kidney cancer are not fully understood. It is known that exposures to heavy metals, halogenated compounds and petroleum hydrocarbons can cause kidney pathology. (15) Animals dosed with chemicals such as nitrosamines, aflatoxin, lead acetate and potassium bromate have developed renal cell carcinoma. (16-18)

2.2.5 Brain (ICD-9: 191)

Several studies have shown occupational exposures to vinyl chloride to be related to development of brain cancer. (197-21) Petrochemical workers exposed to solvents and other organic chemicals including benzene, trichloroethane, and trichloroethene have been shown to be at increased risk for this cancer. (22) These chemicals are known to be present in the emissions from some off-gassing municipal waste landfills.

2.2.6 Non-Hodgkin's lymphoma (ICD-9: 200, 202)

There is evidence that the use of herbicides increases the risk of developing non-Hodgkin's lymphoma. Dioxin, which is often present in phenoxy herbicides, has been reported to cause abnormalities of the immune system in animals. (23) Hardell et al. reported an association between exposure to phenoxy acids and organic solvents and malignant lymphoma (both non-Hodgkin's lymphoma and Hodgkin's disease). (24)

2.2.7 Leukemias (ICD-9: 204-208)

Chronic occupational exposure to benzene in the rubber and petrochemical industries has been associated with elevated risk of leukemia. (25-27) Studies have shown associations between farming and leukemia, suggesting a link between leukemia risk and the use of agricultural chemicals such as insecticides, herbicides and fertilizers. (28-29)

3.0 METHODS

3.1 Summary

In order to evaluate cancer incidence and potential residential exposure to hazardous VOCs from off-gassing landfills, this study combines data on cancer cases and controls for a large group of landfills across New York State. The study area comprises the zip code areas surrounding all New York State landfills for which there was evidence of soil gas migration (off-gassing). The study utilizes a case-control methodology rather than more directly assessing cancer incidence in the combined potential exposure areas surrounding the landfills because the latter approach would require estimation of age-specific populations for areas with very small population. The areas classified as exposed are based on an exposure buffer area surrounding each landfill, and this exposure area does not coincide with census boundaries.

An integral part of this study was the selection of landfills which met the criteria for inclusion as off-gassing. The landfill selection process relied upon exposure assessments based on existing data collected from a variety of sources. The measure of disease, cancer diagnosis, was based on complete ascertainment through the New York State Cancer Registry. The probability of residential location in potential exposure areas surrounding each landfill at time of cancer diagnosis among cases was compared to the probability of residential location in these same areas for selected controls obtained from the New York State Bureau of Vital Statistics Death Certificate files. Deceased controls were used instead of the preferred driver's license controls, which include living and deceased subjects, because motor vehicle records were not available for matching to study cases.

3.2 Case and Control Ascertainment

Cases for this investigation are from the New York State Cancer Registry. By law, hospitals and physicians in New York State who treat patients diagnosed with cancer and laboratories that find evidence of cancer in tissue specimens must report these cases to the New York State Health Department. The reporting to the Registry of all cases of cancer diagnosed in New York State, excluding New York City, began on January 1, 1940. On January 1, 1973, mandatory cancer reporting was extended to include New York City. New York State also has reciprocal interstate reporting agreements. Primary reliance for reporting is from hospitals, with nearly 300 acute care hospitals reporting to the Registry. Completeness of reporting based upon a variety of special studies is estimated to be at least 95%. (30) Information pertaining to the neoplasm is coded by the 9th Revision of the ICD. All data recorded prior to 1979 have been adjusted according to this revision. An examination of the Registry for the period 1978-1981 showed that 87% of neoplasms reported were microscopically confirmed.

Seven cancer sites shown in previous epidemiological (mostly occupational) and toxicological studies to be associated with exposure to chemicals of various types have been defined for the purposes of this study as potentially environmentally sensitive (see section 2.2, above). These cancer sites include:

Liver (ICD-9: 155)
Lung (ICD-9: 162)
Bladder (ICD-9: 188)
Kidney (ICD-9: 189)
Brain (ICD-9: 191)
Non-Hodgkin's lymphoma (ICD-9: 200,202)
Leukemia (ICD-9: 204-208)

Cases include all incident reports of these seven types of cancer to the New York State Cancer Registry from January 1, 1980 through December 31, 1989 with addresses at time of diagnosis in the ZIP codes which include the landfills under investigation. To ensure completeness of locational information, the handful of cancer cases with a missing ZIP code in the counties of interest (fewer than one percent) were reviewed by Cancer Registry staff and a ZIP code designation was assigned.

The control group was selected from New York State's Bureau of Vital Statistics, Death Certificate files. Controls for each sex were selected randomly from all deaths (excluding the seven cancer diagnoses) in the same zip codes as the cases, for the time period, January 1, 1980 to December 31, 1989. Controls for each of the seven cancers were selected separately for males and females, and age frequency-matched in ten-year age groups. This control pool for each sex was selected so that it represents the maximum ratio of controls to cases which could be assembled from the available controls when age-frequency matching in ten-year age groups was performed for each of the seven cancers. Since enough controls were available for a control to case ratio of five to one for all cancers except lung, this ratio was used for the six other cancers. For lung cancer, two controls were selected for each case.

The total number of potential controls from death certificates for the 38 zip codes for the years 1980-1989, was 41,148. SAS software was utilized to randomly draw the required number of controls for each age group from the entire group of available controls. While a control could be selected only once as a control for a specific cancer site, the entire pool of controls was utilized for each cancer. Thus the same control can serve as a control for more than one cancer site. A total of 9,737 controls was drawn from the death certificate pool. Since many of these served as controls for more than one cancer, they represent a total of 32,227 controls in the analysis of seven different cancers for males and females.

The 42 landfills identified as off-gassing based on the criteria described below provided the basis for requesting case and control information from Cancer Registry and Vital Records files by ZIP code. Altogether, 43 ZIP codes were identified as the study area for cases and controls because they had some population within 1000 feet of one of the 42 selected landfill site boundaries. For the selection of zip codes, a distance of 1000 feet was used for all sites as a worst case scenario for the extent of potential methane and/or VOC off-site migration. As described below, once geographic location of addresses was accomplished, four landfills were eliminated from the study due to lack of sufficient numbers of cases and controls (fewer than five) in the landfill's zip code or within ½ mile of the landfill. The following discussion of ascertainment and geographic location of cases and controls is thus based on the amended study area which comprises 38 landfills in 38 ZIP codes. For the seven cancer sites, males and females, a total of 9,674 cases were identified from the New York State Cancer Registry for the 38 zip codes in the study area, for the period 1980-1989.

3.3 Assignment of Residential Locations

All cases and controls were processed according to a standard protocol developed by the NYS-DOH for such purposes to determine the latitude and longitude coordinates for each residential street address. For cases, this is their address at the time of cancer diagnosis. For controls, it is their address at date of death. The assignment of geographic coordinates to addresses utilized computerized methods based on U.S. Census Bureau geographic files and U.S. Postal Service geographic files that match to Census Bureau files. If a coordinate assignment could not be made by means of automated methods then traditional sources of geographic information were used including: street maps and atlases, phone books, city directories, and other listings of street addresses that were available for a particular area. (31-32)

Of the 9,674 cases identified from the New York State Cancer Registry, 644 (6.7%) were not assigned geographic coordinates because of inadequate address information. Ten additional cases were eliminated because their geographic assignments indicated that they resided outside the study area. A total of 9,020 cancer cases remained in the study to be assigned potential exposures. The final group of cases represented 93.2 percent of the original group.

Of the 9,737 controls, 412 (4.2%) were not matched to geographic coordinates because of inadequate address information. An additional 156 were eliminated as controls because their addresses placed them outside the study area. These restrictions resulted in 9,169 controls or 94.0 percent of the original group remaining in the study to be assigned potential exposures. These 9,169 control subjects represented 30,307 controls in the analyses of seven cancer sites for men and women.

3.4 Classification of Off-Gassing Landfill Exposure

3.4.1 Landfill Selection

Landfill selection began with the identification of all sites listed in the Department of Environmental Conservation's New York State Registry of Inactive Hazardous Waste Sites, exclusive of sites in New York City. (33) New York City was excluded because obtaining death certificate information from New York City was not possible within the time-frame of this study. Additionally, New York City may be sufficiently different in terms of potential exposures to make comparison with the rest of the state difficult. Location in one of the remaining 57 counties in New York State was thus the first criterion for a landfill's inclusion in the study.

The investigators originally intended to obtain information on eligible landfills from a variety of sources in addition to the Department of Environmental Conservation's (DEC) State Registry of Inactive Hazardous Waste Sites, including State Department of Health site investigators, County health departments and other listings from the DEC landfill closure section. However, the information obtained from different sources was not consistent and contained many important data gaps. Therefore, only sites that were listed on the State Registry of Inactive Hazardous Waste Sites were included in the study. At the time of initial site identification (December, 1992) there were 1,159 unique sites in this registry.

The Hazardous Waste Site remedial program, of which the Registry is one element, was launched by New York State in 1978. The New York State Legislature enacted the Remedial Treatment of Inactive Hazardous Waste Sites Act in 1979. This law gave the state's Department of Environmental Conservation (DEC) the authority to compel responsible parties to clean up inactive hazardous waste sites. It required DEC to establish and maintain a registry of inactive hazardous waste disposal sites. Each county is required to report all of its suspected inactive hazardous waste sites to the Department of Environmental Conservation. The DEC must investigate all sites suspected of containing hazardous wastes and include in the registry any sites which are shown to contain hazardous waste. State law defines a hazardous waste as a product which results from an industrial process, or is a "listed" waste (regulated under federal Superfund law), or is a substance that is toxic, corrosive, reactive, or ignitable. For the site to be included on the Registry, the waste at the site must pose a "significant threat" to human health or the environment. Hazardous waste sites which currently accept hazardous waste and which do not require remediation are not generally included in the Registry. Landfills suggested for the Registry which were later "de-listed" for lack of evidence of hazardous waste were also considered for inclusion in the study.

Landfills were selected from the Inactive Hazardous Waste Site Registry in a multi-step process designed to minimize the amount of time required to gather data from paper files and to ensure that more effort was expended on those sites most likely to be included in the cancer incidence study. Since off-gassing was the hypothesized contaminant release mechanism, the investigators were seeking sites where significant amounts of waste containing decomposable organic matter were buried. This process first involved identification of sites from the registry that could be characterized as municipal landfills. This was done by first selecting sites that contained the words 'landfill' or 'dump' in their names or descriptions. Additional sites that could be characterized as municipal landfills that did not meet this criterion were identified by a more thorough review of their site descriptions.

Since no landfill can contribute to residential exposures unless there are people residing nearby, all sites first had to meet a general population criterion before their characteristics and potential for exposure were reviewed. This criterion was based on 1990 U.S. Census block population data and required either 1000 people to be located within one mile or 300 people to be within a half mile of a point representing the location of the site.

A general review of time of operation, site characteristics and information on environmental sampling was then conducted. To be considered for further review, a site had to have an active waste disposal cell sometime between 1960 and 1979. Eligible sites were then assigned to one of three general categories:

1) Definite evidence of methane or VOC contamination
2) Evidence of potential methane or VOC contamination
3) No evidence of methane or VOC contamination

All landfills in category 1, definite evidence of methane or VOC contamination, were eligible for the detailed review. An intermediate review of landfills in the second category, evidence of potential methane or VOC contamination, was conducted to identify those most likely to present an exposure problem. Landfills in the third category, no evidence of methane or VOC contamination, were removed from further consideration.

The landfills in categories 1 and 2 then received a detailed examination of site characteristics and any available environmental monitoring data for methane or total VOCs or sampling data for methane or specific VOCs. This additional review characterized the level and extent of contamination in soil gas and ambient air associated with each landfill. A detailed evaluation of other site characteristics (size, presence and type of liner, presence and type of gas collection system) related to extent of methane migration in soil gas was also part of this review.

A final assessment of each site was conducted based on the size and shape of the actual landfill property. For the remaining landfills individual site maps were prepared and entered into a computerized mapping system so that a more detailed examination of nearby population could determine for each site whether there were people potentially exposed to off-gassing landfill emissions.

Identification of sites from the registry that could be characterized as municipal waste landfills yielded 245 sites. When the size of the population located within one mile or within a half mile of a point representing the location of each landfill was assessed, 131 sites remained. Based on the existence of an active cell sometime between 1960 and 1979 and evidence of either a methane or a VOC problem, the 131 sites were classified into three categories. Thirty-one sites were in the first category, strongly evident methane or VOC contamination; 52 were in the second category, evidence for potential methane or VOC contamination; and 48 had no evidence of methane or VOC contamination, and were eliminated from further consideration. This left 83 sites for further consideration.

The remaining 83 landfills received further review. After those with no evidence of methane or VOC contamination based on more detailed inspection of site characteristics and environmental sampling and monitoring were eliminated, a total of 49 sites remained. Sites were eliminated for a variety of reasons. Sites for which the data were incomplete were eliminated if other factors pointed towards very low probability of methane production. For some sites which contained mostly industrial waste, there was no evidence that biodegradable material had been buried. Some sites with no soil gas or air sampling data did have groundwater sampling data. If extensive groundwater data showed no evidence of significant VOC contamination, sites were dropped. Sites were also dropped if there was no evidence of methane or any VOCs of concern or if the geological data pointed toward very low probability of methane migration off-site. If the data were insufficient to make a judgment, a site was dropped rather than included as potentially off-gassing.

Finally, an assessment of potential exposure to nearby population was made by evaluating maps detailing the size and shape of the actual landfill property and nearby population by block group. Seven sites were dropped because the detailed maps showed fewer than ten people in nearby block groups. This evaluation left 42 landfill sites remaining in the study.

After the assignment of geographic location to cancer cases and selected controls, landfills that had ZIP code areas with fewer than five cases and controls combined or with no cases or controls within one half mile of a landfill potential exposure buffer were removed from further consideration. This resulted in removal of four landfills from the study: one in a rural area where address-matching was not successful, two with fewer than five cases and controls in the entire ZIP code, and one where no cases and controls were located within one half-mile of the landfill buffer. The final number of landfills in the study was then 38, and these 38 landfills were located in or near 38 ZIP code areas which comprise the study population. (Table 3.1) (Figure 3.1)

3.4.2 Landfill Ranking

A detailed assessment of site data and characteristics for eligible landfills was recorded on a Methane Landfill Data Inventory Form sheet (Appendix A). Data were obtained for site characteristics that would most likely affect methane generation and off-site migration of methane in the vadose zone (the portion of subsurface soil that is above groundwater). Data were available for characteristics such as landfill size and age, type of waste disposed (i.e., municipal, industrial, commercial, hazardous), presence or absence of a gas collection system, waste quantity, porosities of adjacent soils and whether the landfill was capped.

Sampling data were also reviewed. For each site it was determined whether there were on-site and/or off-site soil gas data for methane and/or VOCs, on-site and/or off-site ambient air sample data for methane and/or VOCs, on-site and/or off-site ambient air monitoring data for methane and/or VOCs (i.e., monitoring for total VOCs with an HNu PID and for methane gas with a combustible gas meter) and indoor air sampling data (on and/or off-site) for methane and/or VOCs. The sites were then ranked based on the extent of these types of sampling data. Three categories of sites emerged, based on the extent of sampling data available:

A. Quantitative - Both on- and off-site sampling data for methane or VOCs
B. Semi-quantitative - Only on-site sampling data for methane or VOCs
C. Qualitative - Monitoring data for total ambient VOCs only, no methane sampling data or specific VOC sampling data available

Landfills that had both on- and off-site soil gas sampling data for methane and/or VOCs and/or on- and off-site air sampling data for methane and/or VOCs were assigned to the quantitative category. For these sites, methane (and possibly other VOCs) had been detected at some measured distance off-site in the soil gas and/or the ambient air. These sites were expected to provide the basis for evaluating existing mathematical models that predict off-site gas migration. (34) The actual off-site distances at which methane was detected in the soil gas would be compared with the distances predicted by an appropriate model.

For sites with both on- and off-site air sampling data, a similar evaluation of modeling was undertaken. Discussions with other NYS DOH staff with experience in air contaminant dispersion indicated that in their judgment, the dilution effects would be so great that off-site impacts to ambient air levels of VOCs or methane would be nearly the same as expected background levels. In order to assess the potential for off-site ambient air exposure, an emission rate was estimated using the on-site data and a model was used, with this emission rate, to calculate the corresponding off-site concentrations. The modeled (predicted) off-site ambient air concentrations were then compared with the actual, measured off-site concentrations.

If there was agreement between the modeled and actual distances for off-site soil gas migration, modeling would be applied to sites in category B for which only on-site soil gas sampling data were available. Also, if there was agreement between the modeled and actual off-site concentrations of methane and/or VOCs in ambient air, models would be used to estimate air concentrations for category B sites. Information available from sites in category A would thus be used to determine whether mathematical models could be used to predict the distance of off-site methane migration or ambient air concentrations for the sites in category B.

The third category contained sites for which the basis of determining the distance of off-site methane migration was qualitative. These sites had neither on- nor off-site soil gas (methane) data. They also had neither on- nor off-site contaminant-specific air sampling data. A few of the sites in this category did have ambient air monitoring data for total VOCs on- or off-site. Despite the lack of quantitative data, these sites potentially had a methane problem and/or were alleged or confirmed to have VOCs, and thus warranted further study. For these sites, the predicted off-site distance of methane migration or ambient air concentrations of methane or VOCs were to be obtained by matching site characteristics to category A or B sites, and assigning appropriate measured or modeled off-site migration distances or concentration levels available from comparable sites.

An attempt was made to implement a steady-state vadose zone contaminant dispersion equation for predicting indoor air concentrations of VOCs and, using pre-determined indoor air concentrations, solve for the distance from the landfill. (34) However, detailed review of the 42 sites initially selected for further study revealed that too few sites had adequate data for the variables required in the model considered for use in predicting off-site methane migration distances. For the majority of sites, data could not be obtained for soil moisture content, bulk density of the soils, organic content of soils, cap or cover thickness and gas pressures within the landfills.

Eleven sites were classified as category A for having both on- and off-site soil gas sampling data for methane. Six of these eleven sites had both on- and off-site soil gas data for VOCs and three of the remaining five had at least on-site soil gas data for VOCs. Five of these sites had sufficient data for assessing whether modeling might be useful for predicting off-site soil gas exposures. For each of these five sites, the distance from the landfill at which soil gas was detected was plotted against the on-site methane concentration. The plots did not reveal any evidence that distance at which methane was detected was a function of methane concentration. Moreover, distance was not a uniformly decreasing function of concentration. The differences in off-site distances at which methane ceased to be detected could not be associated with any specific factors such as porosity of the soils, size of the landfill, age of the landfill, or depth of buried waste. Despite the seeming lack of association between on- and off-site contaminant levels among the category A landfills, a model was attempted. The predicted distances for off-site gas migration differed from the actual distances by more than an order of magnitude. Review of the literature did not reveal any other pertinent models for predicting off-site distances of soil gas migration. (35-48)

For the eleven sites which had both on- and off-site soil gas data for methane and/or VOCs, a potential exposure buffer zone surrounding the landfill boundary at a uniform distance of 250, 500, 750 or 1000 feet was established, based on the actual off-site distances (rounded to the nearest 250 feet category) at which methane had been detected in the soil gas. Any population residing within the buffer would be considered to have an exposure to methane and/or VOCs via the soil gas. Of the eleven sites, seven were assigned buffer widths of 250 feet, three were assigned buffers of 500 feet, and one was assigned a buffer of 1,000 feet. (See Table 3.2 for buffer size and category for each final study site.)

There were 15 category B sites, with only on-site soil gas data for methane and/or VOCs. Eight sites had on-site soil gas sampling data for both methane and VOCs, five sites had only on-site soil gas data for methane, and two sites had only on-site soil gas data for VOCs. The two sites with only VOC data were thought to potentially have some level of methane in the soil gas. These two sites were assigned the smallest buffer width, 250 feet. The other thirteen sites had significant levels of methane near the site perimeters, indicating that soil gas was probably migrating off-site. Migration distance was estimated for each site based on site characteristics and input from DOH site investigators. For all but two of the 15 sites, that distance was equal to the most conservative buffer distance of 250 feet. Two sites were assigned buffer distances of 500 feet, based on the judgment of the site investigator. (One of these sites was later eliminated from the study).

The VOCs detected at the 25 category A and category B sites are listed in Table 3.3. The VOCs detected most often in on-site soil gas at these sites were tetrachloroethene (PCE or perc), trichloroethene (TCE), toluene, 1,1,1 trichloroethane (TCA), benzene, vinyl chloride, xylene, ethylbenzene, methylene chloride, 1,2 dichloroethene and chloroform. These frequently detected chemicals should be considered indicators of chemical contamination. The soil gas likely contained other chemicals in addition to those for which it was monitored.

There were thirteen sites in category C, with no on-site soil gas data for either methane or VOCs. For these sites, the only basis for assuming that off-site migration of methane in soil gas occurred was from site characteristics and information about the landfill contents. In other words, methane was likely to have been generated on site in the soil gas and could have migrated off site. For each of these sites, a potential exposure area or buffer with a width of 250 feet was assigned.

Three sites did not fit into any category because they lacked any on-site soil gas data, but did have off-site soil gas data showing methane at some distance from the site. Two of these sites were assigned a buffer distance of 250 feet. The third site was assigned a buffer distance of 500 feet based on the judgment of the site investigator. (This site was later eliminated from the study.) (These sites are labeled category D in Table 3.2.)

Only six of the 42 sites had on-site air sampling data for methane. Of these six sites, two also had off-site air sampling data for methane. Additionally, all six of these sites had on-site ambient air sampling data for VOCs. Each site was reviewed in terms of data quality, sampling methods and meteorological data at sampling time. The data were not sufficient for estimating emission rates from gas vents or on-site soils in order to model off-site concentrations. The two sites with both on- and off-site ambient air data for methane were compared. No consistent associations between the on- and off-site concentrations were evident in the comparison of these two sites.

All six sites with on-site air sampling data had either active or passive venting systems installed at the time of sampling. From this data it was evident that for sites with gas collection systems, the levels of methane and/or VOCs showed a decrease of two orders of magnitude a short downwind distance from the vents. This supports the conclusion that there was not likely to be an off-site ambient air problem. One site (152005, Blydenburgh) with elevated levels of methane off-site downwind was an exception, but results of sampling for VOCs were inconclusive. Data for these few sites were reviewed with site investigation and exposure assessment staff and it was their conclusion that this limited data validated their initial assumption that the air pathway did not constitute a significant source for methane and VOC migration off-site. (One of the six sites with on-site air sampling data was later eliminated from the study because fewer than five case and control addresses were located nearby).

Four sites were eliminated after the assignment of geographic location of cancer case and control addresses. Three sites were eliminated because fewer than five case and control residences were located in the area near the sites. One of these sites was a category A site which had been assigned a 250 feet buffer. The second site eliminated was the category B site which was assigned a buffer distance of 500 feet, based on the judgment of the site investigator. The third site eliminated for lack of nearby population was the exceptional site which lacked any on-site soil gas data, but had off-site soil gas data, and was assigned a buffer width of 500 feet. A fourth site, eliminated because address-matching was unsuccessful, was a category C site with a 250 foot buffer.

Potential exposure of residents was classified according to location of their homes in a zone or "buffer" of potential impact around each of the 38 landfills included in the study. These areas were expected to have similar exposure potential; sites showing evidence of further off-site methane movement were given larger buffers. The final site list included 33 sites with buffers of 250 feet, four sites with buffers of 500 feet, and one site with a buffer of 1,000 feet. Of the total 9,020 cancer cases, 49 (0.54%) had addresses within these buffers and were classified as potentially exposed to off-gassing landfills. Of the total 9,169 controls, 36 (0.39%) were classified as potentially exposed.

An additional area of potential exposure, which included 500 additional feet beyond the landfill exposure buffer, was assigned to study subjects. This classification was assumed to represent potential exposure probability greater than zero, but lower than that of the buffer zone. For the crude odds ratio estimates, this classification of potential exposure is assigned to subjects living within the landfill buffer or within 500 feet of the landfill buffer boundary. This less conservative measure of potential exposure was assigned to 173 cases (1.92%) and 173 controls (1.89%). In multivariate analyses, the study subjects residing outside the landfill buffer, but within 500 feet of the buffer, were assigned to this hypothetically lower gradient level of potential exposure.

For most of the landfills in this study there were no data showing whether methane or VOCs had moved away from the landfill into nearby homes or buildings. For three of the study's landfills, indoor air sampling results were available. After several small furnace area explosions occurred near Port Washington Landfill, air was sampled in a few homes in 1981. Levels of vinyl chloride, benzene, 1,1,1-trichloroethane, and 1,1,2-trichloroethane in these samples showed VOC contamination. At two other sites where sampling was done, VOC contamination of indoor air was not found.

3.5 Other Potential Environmental Exposures

Two indicators of other potential environmental exposures were also assigned to case and control subjects. These variables are indicators of other potential exposures to hazardous waste and industrial emissions. They are included in order to control for large differences in concentration of hazardous waste sites and industry among regions of New York State. The first such indicator is residence within 1500 feet of a hazardous waste site listed in the New York State Department of Environmental Conservation Inactive Hazardous Waste Site Registry. The New York State Inactive Hazardous Waste Site Registry is described above in section 3.4.1. Non-off-gassing landfills and other hazardous waste sites could be potential sources of residential exposure to VOCs through groundwater contamination. If the drinking water supply is from a VOC-contaminated aquifer or if contaminated water volatilizes in a flooded basement, exposure to VOCs through ingestion and/or inhalation is possible.

Toxic Release Inventory (TRI) data were also used to indicate potential exposure to air emissions from industry. (49) The Toxic Release Inventory is mandated by the federal Emergency Planning and Community Right-to-Know Act of 1986. Some manufacturing facilities are required to annually report estimated releases to the environment of specified hazardous substances. These releases include air emissions, water discharges, releases to land and transfers to publicly-owned treatment works. A facility must report this data if it is classified as a manufacturing facility (Standard Industrial Classification major group numbers 20-39), has ten or more employees, and manufactures or processes 25,000 pounds or more or otherwise uses 10,000 pounds or more of listed toxic chemicals or chemical categories. (50)

Cases and controls residing within one-half mile of a facility reporting air releases of chemicals with cancer potency factors in the 1989 Toxic Release Inventory were classified as potentially exposed to industrial air emissions. There were 71 such manufacturing facilities in the study area reporting estimated TRI chemical emissions for 1989. Although TRI data were first available for 1988, the locational latitude and longitude data supplied by the facilities themselves were of poor quality. This study utilized the 1989 Toxic Release Inventory because the locational data for this year were verified and corrected. (51) The list of chemicals with cancer potency factors was obtained from the Integrated Risk Information System of the US EPA. (52,53) While the timing of these emissions is not appropriate for assessing actual exposures which may be related to the initiation of cancer, ten to thirty years prior to diagnosis (1978-1987), this data source was the best available indicator for potential exposure to industrial emissions. 371 cases (4.11%) and 453 controls (4.94%) were located within one-half mile of a Toxic Release Inventory facility which reported air release of chemicals with cancer potency factors in 1989. 361 cases (4.00%) and 552 controls (6.02) were located within 1500 feet of an inactive hazardous waste site listed on the New York State Registry, but not included in the study as an off-gassing landfill. In addition, 29 cases and 26 controls, not classified above as exposed to off-gassing landfills, were located within 1500 feet of the off-gassing landfills.

3.6 Demographic Indicator Variables

After geographic coordinates were assigned through address-matching to cases and controls, the location of cases and controls with respect to other digital map files maintained in the geographic information system (GIS) was undertaken. Both the census tract and block group of residence were used to assign indicators of socio-economic status, population density and length of time at residence. (54) The median income level of households in the block group in which the residence is located was used as the indicator of socio-economic status. The income information for calendar year 1989 was acquired from the census questionnaire distributed to all households in 1990.

The other socio-economic indicators, percent of employed persons who are in 'blue-collar' occupations, the percent of population with less than a high school education, and percent of householders who have resided for fewer than ten years at their current address, were derived from interview questions asked of a sample of persons in the 1990 census. Percent blue collar refers to the percent of employed persons who are employed in the census occupational category labeled "operators, fabricators, and laborers." This group of occupations includes machine operators, assemblers, and inspectors; transportation and material moving occupations; and handlers, equipment cleaners, helpers, and laborers. The methods by which these data were assembled for the 1990 Census are described in detail in technical documentation for the 1990 Census of Population and Housing. (55) The variable representing population density is based on a calculation of population per square mile in the block group.

3.7 Statistical Analysis

The hypotheses that exposure to hazardous VOCs from residence near off-gassing landfills could increase the risk for liver cancer, lung cancer, bladder cancer, kidney cancer, brain cancer, non-Hodgkin's lymphoma, or leukemia were tested in the analyses. Crude odds ratios were calculated to compare the odds of residing in the landfill potential exposure areas for cases to the odds of residing in the landfill potential exposure areas among controls. Crude odds ratios were also calculated for residing in the area extending 500 feet from the landfill potential exposure area (buffer). SAS and EpiInfo software were used to calculate odds ratios and confidence intervals. (56,57) While the statistical analysis does not include the testing of hypotheses concerning other potential exposures, the crude odds ratios for residence near other hazardous waste sites and TRI facilities are presented in order to consider their role in the models that produce the adjusted odds ratios presented below.

Possible confounding in these data was assessed by examining the distribution among study subjects of other potential environmental exposures, a nearby hazardous waste site or nearby source of air emissions. Demographic factors which might confound the relationship between exposure and disease were examined by evaluating block-group level variables from 1990 census files, including socioeconomic status and length of time at current residence. Confounding was assessed by testing for associations between these environmental and demographic factors and disease status as well as exposure status.

Finally, logistic regression modeling was employed in order to control for confounding and to show how the inclusion of covariates affected the off-gassing landfill exposure odds ratios. Environmental variables based on residential proximity to other hazardous waste sites or industrial facilities, demographic variables from census block groups, and interaction variables were added in order to better assess the primary hypotheses concerning residence near off-gassing landfills and the seven cancer sites for men and women. Adjusted odds ratios for residence in the off-gassing landfill potential exposure areas were estimated in models that include other variables that contribute to the model's predictive ability. Following Hosmer and Lemeshow, the variables included in the final models were chosen in a stepwise process with $p<=.20$ for each variable remaining in the model. (58) SAS software was used to estimate multiple logistic regression model parameters and statistics. (56)

The variables considered for inclusion in the models include three environmental variables based on residential location near the off-gassing landfill buffers, other hazardous waste sites and industrial facilities. The additional off-gassing landfill exposure variable indicates whether the residence at date of cancer diagnosis for cases, or date of death for controls, was within 500 feet of the landfill exposure buffer. This variable is included as a possible gradient of the primary exposure variable. Subjects in this category have some potential to have been exposed to off-gassing landfills, although their probability of exposure is considered to be much lower than those study subjects residing in the landfill buffers.

The two other environmental variables are also based on residential location. Residence within one-half mile of a TRI facility is included as a proxy to control for potential exposures to industrial emissions. Residence within 1500 feet of other hazardous waste sites is included in order to control for other potential exposures, through drinking water, for example, to hazardous waste sites. These environmental variables are imprecise indicators of potential exposure but may aid in controlling for large differences in industrial concentration and numbers of hazardous waste sites. The inclusion of these variables in the models is for the purpose of estimating adjusted odds ratios for the primary exposure variable, residence near off-gassing landfills. The magnitude and statistical significance of the parameter estimates for the control variables are not being evaluated in order to test additional hypotheses about these potential exposures. They are included based on the assumption that they need to be taken into account because they might contribute to cancer risk.

The three demographic variables, low income, short duration of residence, and high population density, evaluated in the logistic regression models, are ecological. They represent neighborhood rather than individual characteristics. They are included in order to control for differences in socio-economic status and other factors among the various areas of the state included in the study. Socioeconomic differences are associated with lifestyle differences which affect health status, including premature mortality, differential access to medical care, and differential diagnostic accuracy and record-keeping (diagnostic bias).

Low income is defined as being among the lowest 20% in terms of block group income among study subjects. Short duration of residence is defined as residence in a block group in the highest ten percent for percentage of households with less than ten years at their current address. Since cancer develops over a period of years, with initiating events usually estimated as occurring at least ten years prior to diagnosis, this variable may help in distinguishing the geographic areas where current residence is less likely to have been a long-term residence with any potential relationship to cancer etiology. The off-gassing landfills in this study were active between 1960 and 1979, and the cancer cases were diagnosed between 1980 and 1989. This time-frame is consistent with a chronological exposure-effect relationship, and a period of latency between potential residential exposure and diagnosis is possible although not guaranteed in this thirty-year time-frame. High population density is defined as residence in a block group in the highest ten percent of study subjects' block group population density. This variable is included because it has shown a positive relationship to cancer risk in regional comparisons. (59)

Interactions between demographic and environmental variables were also considered for inclusion in the logistic regression models. Four interaction variables were identified that might play important roles in predicting health outcomes. These included interactions between living near a hazardous waste site and income level, living near a hazardous waste site and population density level, living near an industrial facility and income level, and living near an industrial facility and population density level. For the interaction variables, study subjects were given the value of the decile for the demographic variable (income or population density) if they resided near a hazardous waste site or a TRI facility.

4.0 RESULTS

4.1 Summary

In the following analyses, odds ratios are the basic tool for evaluating the hypothesis that residence near off-gassing landfills may affect cancer risk. General descriptive data on other environmental and demographic variables are provided for cases and controls for the seven cancers. Exposed and unexposed study subject variable values are also shown in order to address issues of potential confounding. Logistic regression models are then presented and compared to further evaluate the primary hypothesis for the specific cancer sites. As described in the following presentation, in this analysis, residence within the off-gassing landfill buffers produces odds ratio estimates which show statistically significant elevations for two cancers, bladder cancer in females and leukemia in females. These elevated odds ratios remain statistically significant in models that control for other environmental and demographic variables.

4.2 Study Subject Characteristics

Mean age for cases and controls varies from age 54 for brain cancers in males to age 69 for bladder cancer in females. (Table 4.1 and Table 4.2) Mean block group income ranges from a low of about $42,000 for controls for several cancers in females to a high of $52,000 for cases of brain cancer in men. Block group income shows a consistent tendency to be higher for cases than controls. Mean block group population density, which is population per square mile in the block group varies from about 3,000 to 5,000. A census variable indicating the percentage of block group households who have lived in their current residence fewer than ten years is also shown. Geographic mobility is evident here, with the average percent of households having resided in their current household fewer than ten years varying only slightly among groups of study subjects, from 48% to 50%. For descriptive purposes, the percent of the study cases classified as exposed to other non-off-gassing hazardous waste sites or TRI facilities is also shown.

4.3 Potential Confounders

Each demographic variable is shown for exposed and non-exposed subjects. Of particular interest are the income variables which differed between cases and controls. A pattern of differences appears between exposed and unexposed, with exposed subjects scoring higher values for mean income. (Table 4.3 and Table 4.4) Population density values for females do not show a pattern of difference between exposed and non-exposed subjects. For men, population density is consistently higher for unexposed subjects. For all the cancers in females, exposed subjects score lower than non-exposed subjects on the variable indicating percent of people in each female's census block who have resided in their homes less than ten years. This indicates that the potentially exposed females live in somewhat more stable neighborhoods than the unexposed female study subjects. For the cancers in males, this difference does not appear as consistently.

Study subjects classified as exposed to off-gassing landfills tend to live near other hazardous waste sites much more often than study subjects who are not exposed to off-gassing landfills. This overlapping of exposures does not hold for TRI emissions. There is no subject exposed to an off-gassing landfill who also lives near a TRI facility.

The variety of associations presented above requires further examination. The association between income and exposure to off-gassing landfills (Tables 4.3 and 4.4) raises the potential for confounding, particularly for the possibility that higher income people are more likely to be diagnosed with cancer and are more likely to live near landfills, thus perhaps falsely creating the impression that the landfills, rather than income differentials are related to disease status.

Because this study combines information from various regions which differ greatly in terms of income, and may also differ in probability of exposure to off-gassing landfills, the potential exists for confounding by income. Although differences in the probability of exposure among regions would affect cases and controls equally, if there is also more accurate diagnosis and more complete reporting of cancer in the area (or other income-associated reason for higher cancer incidence) with greater probability of exposure compared with the area with less probability of exposure, then an elevation of the proportion of cases who are exposed could be due to the income (and associated cancer diagnosis and reporting) difference.

Regional demographic differences in New York State, particularly between upstate areas and suburban Long Island may be playing a role in these data. The descriptive data for the differences between all cases and controls and all exposed versus unexposed subjects in the study (Table 4.5) can be compared to the differences between these groups within the regions. (Table 4.6 and Table 4.7) While the income differences between the cases and controls and exposed and unexposed in the whole study group again show that incomes are higher for cases and for exposed subjects, when the regions are viewed separately, this consistent relationship disappears. It is evident that the higher average incomes in Nassau and Suffolk Counties and the higher probability of exposure in those counties is a confounding variable in the apparent relationship between income and exposure seen in the combined data. Looking within each region separately, income is higher for cases than controls, but income is not higher for potentially exposed female subjects within either Nassau and Suffolk or the upstate regions. For males, income is higher for cancer cases, but not for potentially exposed subjects in Nassau and Suffolk; in the upstate zip codes, income is higher, but not significantly higher, for potentially exposed subjects.

Regional differences in proportion of subjects exposed combines with the income differences to produce confounding. The percent of female study subjects exposed is four times greater in Nassau and Suffolk (1.17%) than in the upstate portion of the study area (0.27%). Males are twice as likely to be exposed in Nassau and Suffolk (0.50%) as in upstate areas (0.21%). For both regions and both sexes the proportion of cases exposed is higher than the proportion of controls, however. One way to address this confounding would be to control for region of residence. Since region of residence is important because of potential medical/diagnostic or other effects associated with income, demographic variables are instead used to control for regional income differences. In the logistic regression analyses presented in Section 4.5, adjusted odds ratios for residence within the off-gassing landfill buffer are presented in models which control simultaneously for other environmental and demographic variables.

4.4 Crude Odds Ratios

4.4.1 Off-Gassing Landfills

Crude odds ratios were estimated to evaluate the relative risk associated with living within an off-gassing landfill buffer. Odds ratios were calculated separately for females and males for seven cancers. (Table 4.8 and Table 4.9) Crude odds ratios for females showed non-statistically significant elevations for five of the seven cancers: liver (4.73, CI= 0.29 - 76.5), lung (1.35, CI=0.60 - 3.05), kidney (2.36, CI=0.43 - 12.95), brain (2.37, CI=0.43 - 13.01), and non-Hodgkin's lymphoma (1.42, CI=0.39 - 5.18). The two other cancers in females, bladder cancer and leukemia, showed significantly elevated odds ratios. For bladder cancer the odds ratio was 4.08 with a confidence interval of 1.36 - 12.21. The result was similar for leukemia, with an odds ratio of 4.76, confidence interval 1.37 - 16.53.

For four cancers in males, liver, kidney, brain and non-Hodgkin's lymphoma, no cases were exposed to off-gassing landfills, so these odds ratio estimates are zero. (Table 4.9) Because very few controls resided in the potential exposure areas, these odds ratios with zero values are not statistically significantly low, however. The crude odds ratio for lung cancer in males showed a non-significant elevation (1.41, CI=0.67 - 2.99), similar to that for lung cancer in females. The two cancers, bladder and leukemia, which were significantly elevated among exposed women were also elevated, but not significantly, for men. The odds ratio for bladder cancer was only slightly elevated and non-significant, 1.18 (CI=0.39 - 3.53). The odds ratio for leukemia in males was also non-significantly elevated, but was somewhat higher, 1.87 (CI=0.59 - 6.00).

When a potential gradient of lower probability for potential exposure, residence within 500 feet of the off-gassing landfill potential exposure area, is evaluated, the number of potentially exposed subjects increases three-fold. (Table 4.10 and Table 4.11) Potentially exposed subjects in this more distant area from the off-gassing landfills are still a small proportion, less than two percent, of the study group. None of these odds ratios are statistically significantly high or low.

4.4.2 TRI Facilities and Other Hazardous Waste Sites

Variables indicating residence near TRI facilities (Table 4.12 and Table 4.13) and other hazardous waste sites (Table 4.14 and Table 4.15) are included in the analysis as measures of other potential environmental exposures which should be controlled for in order to better evaluate the primary hypothesis regarding potential exposure to off-gassing landfills. Residence within one-half mile of any facility reporting air emissions to the Toxic Release Inventory and residence within 1500 feet of any site listed as a hazardous waste site are general indices of other potential exposures. These variables should aid in differentiating among areas with large differences in industrial and hazardous waste site concentration. The crude or unadjusted odds ratios for these two indices are presented for descriptive purposes. The unadjusted odds ratios for residence within one half mile of a TRI facility do not show increased risk for any of the seven cancers due to residing near industries reporting emissions with cancer potency factors to TRI in 1989. Three of the unadjusted odds ratios are significantly below one, for lung, bladder and kidney cancer in females. As described above, no study subject resided near an off-gassing landfill and a TRI site, so these crude odds ratios, which do not take into account the primary exposure to off-gassing landfills for study subjects, are of interest only insofar as they help describe the data.

Crude odds ratios are also shown for residence within 1500 feet of a hazardous waste site listed in the New York State Registry. (Table 4.14 and Table 4.15) There are 71 hazardous waste sites in addition to the 38 off-gassing landfills in the 38 zip codes which comprise the study area. This variable indicates potential exposure to any hazardous waste site, whether or not it is classified as an off-gassing landfill. Residences within 1500 feet of the off-gassing landfills, including those in the exposure buffers and 500 feet from them are also counted as exposed for this index. Most of the odds ratio estimates are below one, but no odds ratio for this factor differs significantly from one. These environmental variables will be discussed further in the following section, when they are evaluated simultaneously with other demographic variables in logistic regression models.

4.5 Logistic Regression Models

4.5.1 Summary

The univariate and multivariate results are shown in Table 4.16 for each cancer site in females and three cancer sites in males to show how the inclusion of other environmental and demographic variables affects the off-gassing landfill exposure odds ratio. Crude and adjusted odds ratios are not presented for the four cancer sites in males where there were no cancer cases residing in the off-gassing landfill buffers. (See Appendix Table B-3 for additional analyses for these four cancers in males.)

Adjusting for the potential environmental confounders and covariates produces higher odds ratios for residence within an off-gassing landfill buffer for all except one of the cancer sites in females and males. Only for kidney cancer in females does the adjusted odds ratio decrease in comparison to the crude odds ratio. The only adjusted odds ratios which are statistically significant, however, are for bladder cancer in females and leukemia in females, the cancers for which the unadjusted odds ratios were also significantly elevated. The variable representing residence in the area more distant from the landfill, within 500 feet of the buffer, contributed strongly enough to be included in only one model, for bladder cancer in females.

4.5.2 Cancers in Females

For liver cancer in females, the estimated elevated odds ratio for residence within the off-gassing landfill buffers increases from 4.73 (CI: 0.29-76.5) in the unadjusted model to 7.90 (CI: 0.41-152) in the adjusted model. The odds ratio remains statistically non-significant however. For lung cancer in females, the adjusted odds ratio for residing in an off-gassing landfill potential exposure area is elevated and slightly higher than the crude odds ratio. (OR= 1.71, CI: 0.73-4.03) The estimated elevated odds ratio is not statistically significant however.

The multiple logistic regression results for bladder cancer in females continue to show a statistically significantly elevated odds ratio for residing in the off-gassing landfill potential exposure area (OR=5.52, CI: 1.67 - 18.2). This is the only cancer site for which residence within the area within 500 feet of the potential exposure area reaches the cut-off significance level for inclusion in the final model. (See Appendix B for presentation of the estimated parameters and statistics for all variables included in the models.)

For kidney cancer in females the adjusted odds ratio (OR=2.25, CI: 0.41-12.4) declines very slightly compared to the crude odds ratios. The odds ratios for residence in the off-gassing landfill buffer are elevated, although not statistically significant. For brain cancer in females, the adjusted odds ratio, like the crude odds ratio, is statistically non-significantly elevated for the off-gassing landfill exposure. The adjusted odds ratio is 3.29 (CI: 0.57-19.1), compared to the crude odds ratio of 2.37. The adjusted odds ratio for residence in the off-gassing landfill potential exposure area for non-Hodgkin's lymphoma in females (OR=2.03, CI: 0.52-7.85) shows a slight increase over the unadjusted odds ratio, but this odds ratio is not statistically significantly elevated.

For leukemia in females, the addition of other environmental and demographic variables slightly increased the estimated elevated odds ratio for residence in the off-gassing landfill buffers (OR=5.13, CI: 1.45 - 18.1). This adjusted odds ratio for potential off-gassing landfill exposure for leukemia in females was, like the crude odds ratio, statistically significantly elevated.

4.5.3 Cancers in Males

For lung cancer in males, the odds ratio for residence in the off-gassing landfill buffers increases very slightly from the unadjusted estimate of 1.41 (CI: 0.67-2.99) to the adjusted estimate of 1.57 (CI: 0.74-3.34), but remains statistically non-significant. The addition of other environmental and demographic variables in models for bladder cancer in males produces model parameters showing slightly higher odds ratios for the adjusted off-gassing landfill buffer potential exposure variable (OR = 1.30, CI: 0.42-3.97) than for the unadjusted odds ratio (OR = 1.18, CI: 0.39-3.53). The final model for leukemia in males produces an estimated odds ratio for residence in the off-gassing landfill buffer which increases to 2.16 (CI: 0.65-7.14) from the unadjusted value of 1.87 (CI: 0.59-6.00). This elevated odds ratio remains statistically non-significant however.

4.6 Exposed Bladder Cancer and Leukemia Cases

More detailed information on cancer diagnosis is available for some cancers, and was evaluated for bladder cancer and leukemia. All the exposed bladder cancer cases in males and females received ICD9 code, 188.9, part unspecified. For exposed leukemia cases in females, no ICD category contains more than one exposed case. The five exposed leukemia cases in females are distributed evenly among chronic lymphoid leukemia (204.1), acute myeloid leukemia (205.0), chronic myeloid leukemia (205.1), acute monocytic leukemia (206.0), and unspecified leukemia (208.9). The exposed leukemia cases in males include two with diagnoses recorded as acute myeloid leukemia (205.0), one chronic myeloid leukemia (205.1), and one acute leukemia of unspecified cell type (208.0).

5.0 DISCUSSION

5.1 Summary

The small percentage of study subjects exposed to off-gassing landfills indicates that if the increased risk for cancer associated with residence near off-gassing landfills found in this study is based on a causal relationship, the risk in the population that is attributable to this specific cause is very small. On the other hand, the small proportion of study subjects potentially exposed to VOCs from off-gassing landfills greatly limited the power of this study to detect any association that might exist. The interpretation of the study's findings is additionally limited because individual-level information on environmental exposures and other factors which influence cancer risk were not available. The statistically significant elevation in risk for bladder cancer in females and leukemia among subjects potentially exposed at their residences to VOCs from off-gassing landfills suggests that further study of the health effects of off-gassing landfills is warranted however.

The following sections provide discussion of the study's results, including the process of off-gassing landfill identification, assignment of potential exposures, analysis of risk associated with potential exposures, and assessment of study limitations.

5.2 Landfill Selection Process

The identification of landfills with soil gas migration conditions is particularly important because study subjects classified as non-exposed to the study's landfills may live in close proximity to other landfills or hazardous waste sites. With low exposure prevalence, statistical power is maximized by increasing the exposure measure's specificity rather than sensitivity. Thus it was better to classify as non-exposed those whose exposure status was less certain. The landfill selection process carefully excluded any landfill with no evidence of either methane gas or VOCs. The exclusion rather than inclusion of sites with the least data is also supported by the assumption that if off-gassing was occurring in close proximity to residences, a site would be more likely to have undergone sampling. Site investigators strongly believe that for the landfills where off-site sampling detected methane, the sampling was conducted very soon after methane first migrated off-site.

The initial list of inactive hazardous waste sites from which off-gassing landfills were selected may have provided an incomplete set of sites. Some areas of the state more readily report hazardous waste sites to the registry. Thus, the sites selected may not represent all the off-gassing landfills in the state and it may be inappropriate to estimate statewide relative risks for cancer by residence near off-gassing landfills from these data. However, differences in the frequency and completeness of reporting of sites are regional, so differences in rates of reporting are expected to exist between different zip codes, but not within zip codes. It is also expected that the zip codes in the study represent areas of the state where hazardous waste site reporting is most complete. A thorough investigation of this issue is beyond the scope of the present study.

5.3 Exposure Buffer Assignment

The buffer assignment resulted in 33 out of the 38 landfills receiving buffer widths of only 250 feet. This potential exposure area is primarily based on the assumption that soil gas migration into basements is the pathway of potential exposure to VOCs from off-gassing landfills. Seasonal variation would be expected with the winter months having higher indoor levels due to the chimney effect. Also, if infrastructure such as water, sewer or electric conduits pass between the landfill and the residence, gas flow would be diverted. This situation was not factored into this study. It is also possible that ambient air provided a pathway of exposure for methane and VOCs near some sites. All but five of the final sites lacked any air sampling data for either methane or VOCs. None of these five sites showed an increase in methane levels in off-site ambient air that could definitely be attributed to the site. However, the air sampling data were collected by short-term sampling (generally eight-hour) during only one season. For this pathway, air sampling should be done during worst-case meteorological conditions, during summer months and during rapid changes in barometric pressure. Lacking this level of data for any sites, this study may have prematurely dismissed the air pathway. The potential remains that residents living within several hundred feet of some off-gassing landfills may have been exposed to higher than background levels of VOCs from the landfills via the air pathway.

An additional problem related to the lack of air sampling data is that, for sites with active or passive gas collection/venting systems, the years and length of time of soil gas venting are not accounted for in the exposure estimation for these landfills. Again, the data available did not allow an informed assessment of the effect of soil gas venting on exposure. For many sites with some type of gas control system, it was not possible to tell whether the soil gas sampling had been done while the system was operating. This adds further uncertainty to the available soil gas data. Soil gas venting will decrease the lateral migration of methane in soil gas and increase the levels of methane and VOCs in on-site ambient air. Venting thus could decrease the boundaries of potential off-site soil-gas impact.

During the 1970's and 1980's, the years assessed for potential exposures for this study, active venting systems, which pull soil gas from the site, and may significantly reduce soil gas levels, were installed at eight of the 38 landfills, two in 1978 and 1979, and six between 1982 and 1984. Passive venting systems, which may have less effect on soil gas levels than active systems, were installed at nine sites, one in 1975, two in 1979 and 1981, and six from 1983 to 1991. While the timing of venting system installations for most landfills makes it unlikely that the venting occurred during this study's time-frame for cancer initiation (ten to thirty years prior to case diagnoses from 1980 to 1989), the four venting systems installed from 1975 to 1981 may have influenced relevant exposures. (As of 1997, twenty-two of the study's landfills have methane collection systems in place and four more are planed to be constructed in 1998.)

While the 250 feet exposure buffers were designed to classify potential soil gas exposures, ambient air exposures may be captured by this indicator as well. Venting to air might be expected to increase the probability of ambient air exposures at the same time as it decreases the probability of basement soil gas exposures for residents within the buffer, adding to uncertainty about the pathway of exposure. Another source of measurement error in the indicator of potential exposure to soil gas is that the exposure buffer assumes equivalent soil gas migration in all directions. If exposure is also occurring from ambient air as a result of venting of soil gas, measurement error is again associated with the exposure indicator's inability to predict direction of migration.

5.4 Case and Control Selection

The use of deceased controls limits this study's interpretation because it is possible that the deceased controls are not representative of the population from which the cases are drawn. The socio-economic differences evident between cases and controls support the contention that the deceased controls represent a population with lower socio-economic status than the cases. Demographic information has been shown for cases and controls separately so the reader may further examine this problem. In Section 5.5.2, the effects of this problem on the statistical analysis are discussed further.

Because smoking habits differ between men and women, the use of deceased controls may also have differential impact on the analyses of cancers in females and males, and may present more of a problem in the analyses of cancers in males. For almost every cancer, the proportion of male controls who died of circulatory or respiratory disease is higher than the proportion of female controls dying of these causes. (Table 5.1 and Table 5.2) If smoking was more prevalent among the male controls than the females, and if smoking and off-gassing landfill exposure interact to increase circulatory or respiratory disease risk, or if smoking confounds the relationship in some other way, exposed men might be under represented among the cancer cases, but not because of any protective effect of off-gassing landfill exposures.

5.5 Statistical Results

5.5.1 Crude Odds Ratios

Off-Gassing Landfills

While there is one clear inconsistency between the results for cancers in males and cancers in females, there are also parallel findings that suggest similarities between men and women. The inconsistency is that for females, all the crude odds ratios were elevated, while for four of the cancers in males, there was not a single exposed case, resulting in odds ratio estimates of 0.00. While this may appear suggestive of a protective effect against cancer for men residing in the landfill potential exposure areas, the numbers of controls exposed are also very low, and the 0.00 odds ratios are not statistically significant. It is possible that the use of deceased controls could have influenced the analysis in different ways for men than for women as described in the preceding section. It is also possible that detection bias is a greater issue for the male study subjects because men are less likely than women to seek health care. Similarities between men and women are suggested for three cancers, lung, bladder, and leukemia, that show elevated but not statistically significant odds ratios for exposure to off-gassing landfills.

TRI Facilities and Other Hazardous Waste Sites

No study subject residing in an off-gassing landfill buffer also resided at an address within one-half mile of a 1989 TRI facility. This appearance of non-exposure to TRI facilities of study subjects who were potentially exposed to VOCs from off-gassing landfills may provide part of the explanation for the odds ratios being significantly below one for TRI exposure for three cancers in females, particularly for bladder cancer in females. It must be emphasized, however, that use of the TRI data as an indicator of potential historical exposure to industrial emissions is problematic. The TRI data are estimates of emissions from only a small subset of industrial facilities and are best used even for current purposes as an indicator of geographic areas of potential concern rather than as information on particular chemicals and amounts. Particularly because the time period covered by the TRI data does not reflect the historical nature of potential exposures related to cancer etiology, misclassification of exposures to industrial air emissions may be a problem in this analysis. While TRI facilities in New York State tend to be large facilities with long histories at a particular site, the TRI variable omits industries which were in place during the 1960's and 1970's, but have since closed or moved. Thus, there may be confounding from industrial emissions which is not accounted for by this variable.

The geographic distribution of hazardous waste sites, which are often former industrial sites, also suggests that industries formerly located near the off-gassing landfills may be missing from the TRI data. There is a strong positive association between residence in an off-gassing landfill buffer and residence within 1500 feet of a non-off-gassing hazardous waste site. Of the total cancer cases residing in an off-gassing landfill buffer (50), eleven also resided within 1500 feet of another hazardous waste site. Of the total exposed controls (36) (all cancers combined, counting each control only once), 28 also resided near another hazardous waste site. Yet the crude odds ratios for the combined off-gassing landfill and other hazardous waste site exposure do not provide any evidence for cancer risk being associated with residing within 1500 feet of the non-off-gassing sites. (Table 4.14 and Table 4.15)

5.5.2 Case and Control Demographics

All the mean income estimates except for lung cancer in males show statistically significantly higher incomes for cancer cases than controls. (Table 4.1 and Table 4.2) Since lung cancer is predominantly associated with cigarette smoking, higher smoking prevalence among lower income men may account for this cancer not showing the same income differential as the other cancer sites. One reason for the income differential for the other cancers may be that cancer diagnoses are more accurately and more frequently assigned to people with higher incomes because they have better access to health care. Thus, incomplete ascertainment of cancer among lower income people could result in the appearance of a positive association between income and cancer.

In addition, the study's selection of controls from death certificates may independently contribute to the income differential because it leads to selecting controls who may be more likely than the cases to come from lower income groups. The controls, particularly the large portion of them who died of respiratory disease, may not accurately represent the population from which the cases have been drawn. Important differences may exist between these two populations for risk factors that may be associated with income differences, such as access to comprehensive health care services, and health-related behaviors including diet, smoking and exercise.

However, since we expect that residence near landfills is more likely to be associated with low rather than high incomes, these income-related health factors would probably bias the study's findings towards the null hypothesis. That is, people living near landfills would be more likely to be over-represented among the study's deceased controls rather than the study's cancer cases. Bias resulting from the use of deceased controls would tend to be an obstacle preventing the study from finding an association between residence near off-gassing landfills and cancer. This is consistent with the results from the multivariate logistic regression analyses which show the odds ratios for off-gassing landfill exposure increasing when low income is added to the models.

5.5.3 Logistic Regression Analysis

The multivariate logistic regression analyses provide adjusted odds ratio estimates for the primary exposure under investigation, residence near off-gassing landfills. These adjusted odds ratios take some account of the effects and interactions among other environmental and demographic variables. These other variables are ecological, assigned based on residential location or neighborhood demographics, however. This limits the interpretation of the results. While the other environmental and demographic variables play a significant role in predicting cancer status in some of the models, it is likely that not all such effects have been controlled for in the models. Evaluation of the effects of the covariates provides evidence that the control variables may be acting indirectly in the models as indicators of other economic, social, or behavioral factors. (See Tables B-1, B-2 and B-3 in Appendix B.) These uncertainties and the other methodological limitations inherent in this study design clearly limit the interpretation of the findings. But the findings of consistently elevated odds ratios for residence in off-gassing landfill buffers in the multivariate models, particularly for bladder cancer in females and leukemia in females, suggest that there may be an exposure-disease relationship that warrants attention and further study.

The multivariate models show that the off-gassing landfill potential exposure is not statistically significantly linked to increased risk for the cancer sites in males, nor for liver cancer, lung cancer, kidney cancer, brain cancer or non-Hodgkin's lymphoma in females, when control variables are added. The addition of control variables did, however, increase the magnitudes of all of the landfill potential exposure odds ratios except one that declined very slightly (kidney in females). Two of the adjusted odds ratios, for bladder cancer and leukemia in females, were significantly elevated. The adjusted odds ratios for the other cancer sites for which models were estimated were all elevated as well, although not statistically significantly (liver, lung, kidney, brain and non-Hodgkin's lymphoma in females; and lung, bladder and leukemia in males).

5.6 Study Limitations

Measurement Error

The lack of consistent data for accurately classifying potential exposure to VOCs from off-gassing landfills is clearly a limitation of this study. Because much of the judgment for inclusion or exclusion ultimately relied on qualitative information, it is possible that other investigators may have chosen a different final group of sites. This limitation was addressed by close collaboration between two investigators in this process so that each provided a check on the judgments and decisions made by the other.

The dichotomous classification of potential residential exposure assumes that all subjects living within the exposure buffer are potentially equally exposed to landfill soil gas emissions. Because the extent of soil gas migration from the landfill is not likely to be the same in all directions, or in all units of a multi-unit dwelling, this exposure classification surely results in some misclassification of exposure. Misclassification may also result from inaccuracies in the landfill boundaries used for defining the exposure buffers; landfill boundaries may not accurately represent the location of buried waste. Neither of these sources of misclassification of exposure would differentiate cases from controls, however. This misclassification would be expected to reduce the precision of the odds ratio estimates.

Problems with address-matching, including rural addresses which include rural route numbers rather than street locations and zip code inaccuracies or changes which resulted in cases and controls being eliminated because they did not live in the study area zip codes, reduced the number of cases and controls in the final study by 6.7 and 6.0 percent respectively. There is no reason to suspect that address accuracy or address-matching success differed systematically by case status. It is possible that ascertainment by zip code differed between cases and controls. There could be differences in accuracy of zip code information between the Cancer Registry records and Vital Statistics records, the sources for cases and controls. If addresses near landfills are often on rural routes or otherwise more difficult to locate than other addresses, then the group with less accurate address information might also result in a smaller proportion of addresses being assigned to a landfill exposure buffer. Since there is as yet no information pointing to differential address accuracy for cases and controls, it cannot be predicted in which direction a bias may have been present.

The use of zip codes for defining the geographical study area and for case and control ascertainment is also a limitation. Zip codes can change frequently, particularly in areas with rapid population growth. Because of the flexibility of zip code boundaries over time, the level of accuracy of digitized zip code boundary files used in geographical information systems is not yet documented. There is no reason to suspect that this problem is more or less severe among cases than controls however.

Use of Deceased Controls

As discussed above in Sections 5.4 and 5.5.2, the use of deceased controls may have resulted in the controls representing a different population than the cases. Problems associated with the resulting bias related to income differences are somewhat mitigated by using multiple logistic regression analysis controlling for income and other demographic variables. As discussed below, these ecological indicator variables cannot completely control for effects related to individual social and economic factors. This bias would tend to deflate the estimated odds ratios for residence near off-gassing landfills however.

Missing Variables

An important limitation of this study is the lack of individual-level data on other lifestyle factors or sources of exposure which are potential etiological factors for cancer.

Inability to adjust for such important factors as smoking status or occupation reduces the accuracy of the odds ratios for the risk associated with residence near off-gassing landfills. Because the study analysis used deceased controls, who might be expected to have less healthy lifestyles or working environments than the cases, it may be that an analysis which included individual-level data would result in higher, not lower, estimates of the effects of residence near landfills.

Low Statistical Power

This study resulted in many fewer exposed study subjects than expected. Examination of the sampling data and extensive consultation with staff experienced in air contaminant dispersion resulted in smaller estimates of the off-site distance that VOC contaminated soil gas or air might travel than were expected when the project was begun. As a result, the final study analyses have low statistical power.

Multiple Comparisons

Because this study evaluated cancer incidence data and calculated odds ratios for seven different cancers, separately for males and females, the concern arises that these multiple tests could lead to statistically significant findings by chance, since seven hypotheses were tested for each sex. The statistically significant findings reported here do not rule out the possibility of a positive finding by chance. The small numbers of exposed subjects involved in the positive findings, six exposed bladder cancer cases in females and five exposed leukemia cases in females, also necessitate caution in interpreting the study findings. In regard to the multiple comparison issue, the assumption that the number of exposure-disease hypotheses examined will have a known effect on the probability of a false positive finding is based on assuming that no true associations exist. Since studies such as this one are conducted because it is assumed that real associations may exist, it is appropriate to examine a variety of exposure-disease hypotheses and to evaluate each finding on its merits. (60)

6.0 CONCLUSIONS AND RECOMMENDATIONS

This study was successful in realizing the goal of combining information from a group of off-gassing landfills in New York State in order to evaluate cancer risk associated with potential residential exposure to VOCs from off-gassing landfills. Methods for assigning precise geographic locations for individual residences and landfills were developed. These methods made it possible to evaluate apparent disease clusters based on biologically and environmentally plausible geographic areas rather than having to use political boundaries that may not reflect exposure. The study found no statistically significant increase in cancer risk for five sites: liver, lung, kidney, brain, and non-Hodgkin's lymphoma. The study found a statistically significant elevation of cancer risk for bladder cancer and leukemia for females. In this study, cancer risk was estimated to be four times greater for the potentially exposed study subjects than the presumed non-exposed subjects for both bladder cancer and leukemia in females. The findings for bladder cancer in females are consistent with a slightly elevated, but not statistically significantly elevated estimate of risk for bladder cancer in males. The findings for leukemia in females are consistent with a more strongly suggestive but not statistically significant elevated odds ratio for male leukemia in males. It is important to note that if the apparent association between off-gassing landfills and bladder cancer or leukemia is based on a causal relationship, the risk of these cancers attributable to off-gassing landfills would be very small, less than one percent.

This study is limited in its ability to accurately estimate and classify exposure. It lacks individual-level data on length of residence (length of potential exposure) or contaminants, and other risk factors such as smoking. Given these limitations, the very small numbers of exposed cases and controls upon which the findings are based require that caution be used when drawing conclusions from this study. In order to further assess the study findings, the New York State Department of Health will review medical records for the exposed leukemia and bladder cancer cases in females and males. In addition, for these two cancer types, city directories will be used to find additional information on length of residence within the off-gassing landfill buffers for cases and controls.

The current status of methane gas monitoring and collection at the study's landfills is also being reviewed. If sites are identified in New York State or elsewhere where uncontrolled off-gassing from landfills continues to occur, sampling for off-site contaminants through soil gas migration could assess this study's hypothesis about soil migration as a pathway for exposure. If a site with uncontrolled off-gassing and conditions for soil gas migration is identified with people living nearby, homes bordering the site should be sampled to evaluate whether exposures are occurring through soil gas migration. Appropriate preventive actions could then be taken, if necessary, and follow-up of these people in later years could be done to find out if they experienced unusual health problems.

After New York State (1973) and the federal government (1976) began regulating landfills, existing open dumps were either closed or upgraded to sanitary landfills, which have a clean fill cover placed on top of the solid waste. Most of this study's landfills (30) began operating before 1970. Many of these older landfills were not lined and capped as they would be if constructed today. By the end of the 1980's only three of the study landfills were still operating, and none remain open today. Methane collection systems began to be installed in the late 1970's to decrease methane migration away from the landfills. Twenty-two of the study landfills currently have methane collection systems and four more are planned to be constructed in 1998.

In 1988 the New York State legislature passed the Solid Waste Management Act which set priorities for solid waste management in New York State. It required New York State communities to develop programs following this ordering of priorities: (1) reducing the generation of waste, (2) reusing and recycling, (3) recovering energy from waste that cannot be recycled, and (4) disposing by land burial or other means approved by NYS Department of Environmental Conservation (DEC). Also in 1988, NYS DEC issued the set of complete rules, known as "Part 360," for constructing, operating and closing landfills. The Part 360 regulations also include rules for monitoring landfill conditions after closure. Since 1988, the number of landfills accepting municipal solid waste in New York State has decreased from about 240 to 30. The landfills remaining tend to be large because the rules for building and running landfills are more strict and this makes the larger ones more economical. Many of the remaining landfills are privately owned; others are owned by cities or counties. They are regulated by NYS DEC, Division of Solid and Hazardous Materials.

All of the study's landfills have been investigated by NYS DOH and NYS DEC as inactive hazardous waste sites. These evaluations address the potential for human health problems related to each landfill site. The actions taken to improve conditions at closed landfills depend on specific characteristics at each site. Remedial actions have included installing systems for collecting landfill gas, capping the landfill, collection of leachate (water run-off) from the landfill, intercepting and treating contaminated groundwater plumes, and continued groundwater monitoring and air monitoring of landfill vents.

This study presents an analysis of the relationship between potential exposure to off-gassing landfills in the 1960's and 1970's and seven types of cancers diagnosed among men and women in the 1980's. Because landfill closures and clean-up activities have changed the conditions at New York State's landfills since the time-frame covered by this cancer study, this study's results do not provide us with information about health risks related to living near landfills today. This study's findings point to the desirability of finding populations with documented exposures to specific chemicals and data on levels of exposure, perhaps by using newly developed biomarker techniques, so that future studies on the health effects of off-gassing landfills might lead to more definitive conclusions.

7.0 REFERENCES

1. Howe, H.L. Incidence of Cancer in Census Tracts 3014 and 3010p in Port Washington (Nassau County) New York. New York State Department of Health, Cancer Surveillance Program, 1987.
2. Howe, H.L. and Weinstein, A.L. Report of the Epidemiologic Findings from the Plan of Action Regarding the Investigation of Cancer Incidence in Selected Areas of Port Washington (Nassau County) New York. New York State Department of Health, Cancer Surveillance Program, 1988.
3. Tramontano, R. Human Exposure Potential Ranking Model: Methodology Report, Albany, New York: New York State Department of Health, Bureau of Environmental Exposure Investigation, 1987.
4. Pohland, F. 1986. Critical Review and Summary of Leachate and Gas Production from Landfills. US EPA Report # EPA/600/2-86/073, p. 110.
5. Doll and Peto, Causes of Cancer. Oxford University Press, 1981.
6. Pitot, H.C., Hepatic Neoplasia: Chemical Induction. In Arias, I.M.; Jakoby, W.B.; Popper, H.; Schachter, D.; and Shafritzs, D.A. (eds.): The Liver: Biology and Pathobiology, 2nd Edition, Raven Press, New York, 1988, pp. 1125-1146.
7. Plaa, G.L., Toxic Responses of the Liver. In Amdur, M.O.; Doull, J.; Klaassen, C.D. (eds.): Casarett and Doull's Toxicology: The Basic Science of Poisons, 4th Edition, Pergamon Press, Inc., New York, 1991, pp. 334-353.
8. Jockel, K.; Ahrens, W.; Wichmann, H. et al. Occupational and Environmental Hazards Associated with Lung Cancer. International Journal of Epidemiology 1992, Vol. 21, no. 2, pp. 202-213.
9. Vena, J. Air Pollution as a Risk Factor in Lung Cancer. American Journal of Epidemiology 1982, Vol. 116, pp. 42-56.
10. Jedrychowski, W.; Becher, H.; Wahrendorf, J.; Basa-Cierpialek, Z. A Case-Control Study on Lung Cancer with Special Reference to the Effect of Air Pollution in Poland. Journal of Epidemiology and Community Health 1990, Vol. 44, pp. 114-120.
11. National Cancer Institute, Cancer of the Lung: Research Report. U.S. Department of Health and Human Services, National Institutes of Health, 1987.
12. Silverman, D.T., Morrison, A.S., Devesa S.S. Bladder Cancer. In Schottenfeld D., Fraumeni J. Cancer Epidemiology and Prevention, 2nd Edition. New York: Oxford University Press. 1996, pp. 1156-1179.
13. Piper, J.M., Tonascia J., Matranoski, G.M. Heavy Phenacetin Use and Bladder Cancer in Women aged 20 to 49 Years. New England Journal of Medicine 1985, vol. 313, pp.292-295.
14. Ward E., Carpenter, A., Markowitz S. et al. Excess Number of Bladder Cancers in Workers Exposed to Ortho-toluidine and Aniline. Journal of the National Cancer Institute 1991, vol. 83, pp. 501-506.

15. National Cancer Institute, Adult Kidney Cancer and Wilm's Tumor: Research Report. U.S. Department of Health and Human Services, National Institutes of Health, 1987.
16. Matanoski, G.M. and Elliot, E.A., Kidney Cancer Epidemiology. Epidemiologic Reviews 1981, Vol. 3, pp. 203-229.
17. Hewitt, W.R.; Goldstein, R.S.; Hook, J.B., Toxic Responses of the Kidney. In Amdur, M.O.; Doull, J.; Klaassen, C.D. (eds.) Casarett and Doull's Toxicology: The Basic Science of Poisons, 4th Edition, Pergamon Press, Inc., New York, 1991, pp. 354-382.
18. National Cancer Institute, Cancer of the Kidney: Research Report. U.S. Department of Health and Human Services, National Institutes of Health, 1987
19. Byren, D.; Engholm, G.; Englund, A. et al. Mortality and Cancer Morbidity in a Group of Swedish VCM and PVC Production Workers. Environmental Health Perspectives 1976, Vol. 7, pp. 167-170. .
20. Waxweiler, R.G.; Stringer, W.; Wagoner, J.K. et al. Neoplastic Risk Among Workers Exposed to Vinyl Chloride. Annals of the New York Academy of Science 1976, Vol. 271, pp. 40-48.
21. Apferdorf, R. and Infante, P. Review of Epidemiologic Study Results of Vinyl Chloride Related Compounds. Environmental Health Perspectives 1981, Vol. 41, pp. 221-226.
22. Alexander, V.; Leffingwell, S.S.; Lloyd, J.W.; Waxweiler, R.J.; Miller, R.L. Brain Cancer in Petrochemical Workers: A Case Series Report. American Journal of Industrial Medicine 1980, Vol. 1, pp. 115-123.
23. Thigpen, Faith, McConnel, and Moore. Infectious Immunology 1975, Vol. 12, pp. 1319-324
24. Hardell, L.; Eriksson, M.; Lenner, P.; Lundgreen, E. Malignant Lymphoma and Exposure to Chemicals, Especially Organic Solvents, Chlorophenols and Phenoxy Acids: A Case-Control Study. British Journal of Cancer 1981, Vol. 43, pp. 169-176.
25. McMichael, A.J.; Spirtas, R.; Kupper, L.L.; Gamble, J.F. Solvent Exposure and Leukemia Among Rubber Workers: An Epidemiologic Study. Journal of Occupational Medicine 1975, Vol. 17, pp. 234-239.
26. Infante, P.F.; Rinsky, R.A.; Wagoner, J.K.; Young, R.J. Leukaemia in Benzene Workers. Lancet 1977, Vol. 2, pp. 76-78.
27. Decoufle, P.; Blattner, W.A.; Blair, A. Mortality Among Chemical Workers Exposed to Benzene and Other Agents. Environmental Research 1983, Vol. 30, pp. 16-25.
28. Brandt, I.; Nelson, P.G.; Mitella, F. Occupational Exposure to Petroleum Products in Men with Acute Non-lymphocytic Leukemia. British Medical Journal 1978, Vol. 1, pp. 553.
29. Savitz, D.A. and Pearce, NE. Occupational Leukemias and Lymphomas. Seminars in Occupational Medicine 1987, Vol. 2, No. 4, pp. 283-289.
30. Burnett, W.S., et al. Cancer Incidence by County: 1978-1982, New York State. New York State Department of Health, 1987.
31. Matchmaker/2000 for Windows, Geographic Data Technology, Lyme NH.

32. MapInfo, MapInfo Corporation, Troy NY.
33. New York State Department of Environmental Conservation, Registry of Inactive Hazardous Waste Sites, 1989.
34. Little, J.C.; Daisey, J.M.; Nazaroff, W.W. Transport of Subsurface Contaminants into Buildings. Environ. Sci. Technol. Vol. 26, no. 11, 1992, 2058-2066.
35. EMCON Associates. 1980. Methane Generation and Recovery from Landfills. Ann Arbor, Michigan. Ann Arbor Science Publishers.
36. Ghassemi, M. and Crawford, H. 1986. Leachate collection and gas migration and emission problems at landfills and surface impoundments. EPA/600/52-86/017.
37. Halvadakis, C.P. et al. 1983. Landfill methanogenesis: Literature review and critique. Technical Report No. 271. Department of Civil Engineering, Stanford University.
38. Baker, L.W. and K.P. Mackay. 1985. Screening models for estimating toxic air pollution near a hazardous waste landfill. J. Air Poll. Contr. Assoc. 35: 1190-1195.
39. Harkov, R. et al. 1985. Monitoring volatile organic compounds at hazardous and sanitary landfills in New Jersey. J. Environ. Sci. Health. A20(5): 491-501.
40. Hwang, S.T. 1987. Methods for estimating on-site ambient air concentrations at disposal sites. Nuclear and Chem. Waste Mgmt. 7.
41. Kaplin, E.J. et al. 1986. VOC sampling for emission rate determination and ambient air quality impact on an inactive landfill. Air Pollution Control Association.
42. Pelt, W.R.; Bass, R.L.; Kuo, I.R. and Blackard, A.L. 1991. Landfill Air Emissions Estimation Model User's Manual. EPA/600/S8-90/085.
43. Stephens, R.D. et al. 1986. A multimedia study of hazardous waste landfill gas migration. In: Pollutants in a Multimedia Environment. Y. Cohen (ed). New York, Plenum Press.
44. Thibodeaux, L.J. 1981. Estimating the air emissions of chemicals from hazardous waste landfills. J. Haz. Mat. 4: 235-244.
45. Turner, D.B. 1982. Workbook of Atmospheric Dispersion Estimates. TD-18. US EPA.
46. US EPA. 1989. Review and Evaluation of Area Source Dispersion Algorithms for Emission Sources at Superfund Sites. EPA-450/4-89-020.
47. US EPA. 1990. Air/Superfund National Technical Guidance Study Series. Vol. II. Estimation of Baseline Air Emissions at Superfund Sites. EPA-450/1-89-002a.
48. Wood, J.A. and Porter, M.L. 1986. Hazardous Pollutants in Class II Landfills. South Coast Air Quality Management District, El Monte, CA.
49. United States Environmental Protection Agency, Region II, July 30, 1991b. New York State TRI Diskette.
50. United States Environmental Protection Agency, Office of Toxic Substances, Toxic Chemical Release Inventory Questions and Answers, Revised 1989 Version, January 1990.
51. New York State Parks Management and Research Institute, Locational Verification and Correction of 1989 New York State TRI Facilities, Prepared for the U.S. Environmental Protection Agency, Office of Toxic Substances, August 1993.
52. US EPA. IRIS 1992.

53. NYS DOH, Center for Environmental Health. Applications of Toxic Chemical Release Inventory Data in Risk Screening, Health Studies and Geographic Information Systems. 1994.
54. United States Department of Commerce, Bureau of the Census, 1990 Census of Population and Housing, Summary Tape File 3A (on CD-ROM), 1990.
55. United States Department of Commerce, Bureau of the Census, 1990 Census of Population and Housing, Summary Tape File 3 on CD-ROM, Technical Documentation, 1992.
56. SAS, Release 6.08, Cary NC.
57. EpiInfo, Version 5.01B, CDC, Atlanta GA, 1991.
58. Hosmer DW and Lemeshow S. Applied Logistic Regression. New York: John Wiley & Sons, 1989.
59. Nasca PC, Burnett WS, Greenwald P, et al. Population density as an indicator of urban-rural differences in cancer incidence, upstate New York, 1968-1972. American Journal of Epidemiology 1980; 112:362-75.
60. Salves DA and Olshan AF. Multiple comparisons and related issues in the interpretation of epidemiologic data. American Journal of Epidemiology 1995; 142:9, 904-908.

Table 3.1
Landfill Selection Process

Criterion for Inclusion	Number of Sites Eliminated	Number of Sites Remaining	Zip codes
Municipal landfills		= 245	
Sufficient population located nearby	- 114	= 131	
No evidence of methane or VOCs	- 48	= 83	
More detailed examination of site characteristics	- 34	= 49	
Final assessment of each site situation & nearby population	- 7	= 42	43
Addressing matching results indicate insufficient nearby population	- 4	= 38	38

Table 3.2
Off-Gassing Landfills Selected for Inclusion

Zip Code	County	Site Number	Site Name	Data Type	Buffer Width	LF Acres	Methane Collection**	Active Years	Population in Zip Codes	Population in or near LF Buffer
10543	Westchester	360021	Mamaroneck Srs. Housing	B	250	8	P-1996	50-70	18189	88
10950	Orange	336027	Mayer LF	B	250	20	None	49-75	30548	44
10994	Rockland	344006	Nyack LF	B	250	12	P-TBC1998	51-83	***6868	14
10994,10960	Rockland	344001	Clarkstown Town LF	B	500	80	A-TBC1998	40-90	***21325	75
11040	Nassau	130008	Denton Ave LF	A	250	54	P-1975	53-74	37885	287
11050	Nassau	130025	Port Washington LF	A	1000	53	A&P-1982	74-83	28241	162
11542	Nassau	130032	Garvies Point	B	250	19	None	71-80	24917	<10
11572	Nassau	130023	Oceanside LF	A	250	181	P-1983	62-88	31492	51
11722,11788	Suffolk	152084	Watch Hill Sand & Gravel	B	250	45	P-1988	60s-80	***48568	66
11722,11788	Suffolk	152002	Blydenburgh LF	A	500	55	A-1983	27-90	***48568	891
11725	Suffolk	152043	Smithtown LF	A	250	20	A-1983	10-79	***29928	<10
11725	Suffolk	152044	Smithtown Sanitary LF	C	250	24	A-1984	78-84	***29928	<10
11725	Suffolk	152096	Steck & Philbin	C	250	5	None	70s-80s	29928	590
11725,11731	Suffolk	152040	Huntington LF	A	250	44	A-1982	35-89	***60118	569
11741	Suffolk	152053	Sayville LF	B	250	30	P-1984	38-85	26033	<10
11742	Suffolk	152010	Holtsville LF	D	250	74	A-1979	68-74	10073	121
11754,11787	Suffolk	152097	Star Sand & Gravel	A	250	3	None	78-85	48905	<10
11767,11780	Suffolk	152042	South Montclair Ave LF	D	250	20	A-1978	67-70	***23858	724
11791	Nassau	130011	Syosset LF	A	250	35	P-1981	36-75	25024	298
11804	Nassau	130001	Old Bethpage LF	A	500	65	A-1982	58-86	5257	54
11937	Suffolk	152058	East Hampton LF	C	250	45	A-TBC1998	60-97	12140	51
11968	Suffolk	152052	North Sea LF	B	250	13	P-1988	63-97	10867	25
12078	Fulton	518001	Gloversville LF	C	250	80	P-1997	57-89	25335	291
12144	Rensselaer	442003	Former Rensselaer City LF	C	250	12	None	57-76	19049	1,053
12508	Dutchess	314024	Beacon City LF(inactive)	B	250	5	None	30-68	***20312	<10
12508	Dutchess	314046	Beacon City LF	B	250	17	P-1993	68-83	***20312	129
12603	Dutchess	314047	Dutchess Sanitation	B	250	19	A-1994	71-85	40795	<10
13205	Onondaga	734037	Brighton Ave LF	C	250	35	None	43-78	23052	871
13215	Onondaga	734009	Tripoli LF	B	250	75	P-1984	39-85	12520	55
13492	Oneida	633013	Whitestown Municipal LF	A	500	30	P-1992	67-91	10367	324
13748	Broome	704013	Conklin Dump	B	250	37	P-1994	64-75	4090	<10
14048	Chautauqua	907003	Dunkirk LF	C	250	27	P-1979	66-78	20269	32
14101	Cattaraugus	905021	Machias LF	C	250	7	None	70-80	1850	163
14120	Niagara	932026	Niagara County Refuse	C	250	50	P-TBC1998	69-76	51583	149
14467	Monroe	828037	Henrietta Town Dump	C	250	19	None	50-65	8552	476
14534	Monroe	828048	Pittsford Town Dump	C	250	13	None	33-82	27555	210
14617	Monroe	828009	Old Rochester/Pattonwood	C	250	28	None	56-62	24248	548
14845	Chemung	808011	Horseheads LF	B	250	25	None	40-73	20606	136

*See text p.8 for description of data categories. **A=Active, P=Passive, TBC=To Be Constructed, year installed. ***These sites share zip codes with other sites.

Table 3.3
Volatile Organic Compounds Detected in On-Site Soil Gas at the 25 Study Sites with Sampling Data

CAS Number	Chemical	Count
71-55-6	1,1,1 TCA (Trichloroethane)	9
71-43-2	Benzene	8
108-88-3	Toluene	10
100-41-4	Ethylbenzene	8
75-01-4	Vinyl Chloride	8
1330-20-7	Total Xylenes	8
127-18-4	PCE (tetrachloroethylene)	11
75-09-2	Methylene chloride	7
75-00-3	Chlorethane	3
75-69-4	Trichlorofluoromethane	2
75-35-4	1,1 Dichloroethene	4
75-34-3	1,1 Dichloroethane	5
156-60-5	1,2 Dichloroethene	7
107-06-2	1,2 Dichloroethane	2
67-66-3	Chloroform	6
75-27-4	Bromodichloromethane	1
79-01-6	TCE (Trichloroethylene)	10
67-64-1	Acetone	5
95-50-1	1,2 Dichlorobenzne	3
108-90-7	Chlorobenzene	4
78-93-3	2-Butanone	3
75-15-0	Carbon disulfide	1
56-23-5	Carbon tetrachloride	2
108-10-1	MIBK (4-Methyl-2-pentanone)	1
71-36-3	Butanol	1
141-78-6	Ethyl acetate	1
95-63-6	1,2,4 Trimethylbenzene	1

Table 4.1
Female Study Subject Characteristics

	Liver		Lung		Bladder		Kidney		Brain		NH Lymphoma		Leukemia	
	Case	Control	Case	Control	Case	Control	Case	Control	Case	Control	Case	Control	Case	Control
N	80	375	1570	2970	398	1869	316	1487	243	1146	481	2274	335	1575
Mean Age	68.9	68.4	65.5	65.9	69.1	69.2	63.8	64.1	55.5	56.0	63.2	63.6	61.2	61.3
Mean Income	49.1	41.6**	46.2	42.8**	47.1	42.5**	46.7	42.5**	47.7	42.7**	48.6	42.5**	44.7	42.5**
Mean Population Density	3.18	4.89**	4.53	4.58	5.03	4.65	4.63	4.66	4.53	4.62	4.13	4.59**	4.30	4.65
Mean % Dur. < 10 yrs.	50.2	51.8	49.3	51.1**	48.9	51.1**	48.0	51.3**	48.1	51.7**	47.7	51.0	49.5	51.3**
% Near Haz. waste site	2.50	5.87	3.57	6.53**	3.78	6.37**	4.43	5.92	2.88	5.85	3.12	6.11**	4.18	5.84
% Near TRI facility	5.00	4.27	3.31	5.19**	1.76	4.55**	2.22	4.77**	3.70	4.19	2.91	4.66	4.78	4.19

Table 4.2
Male Study Subject Characteristics

	Liver		Lung		Bladder		Kidney		Brain		NH Lymphoma		Leukemia	
	Case	Control	Case	Control	Case	Control	Case	Control	Case	Control	Case	Control	Case	Control
N	136	638	2721	5116	1054	4958	446	2093	275	1283	540	2532	427	1991
Mean Age	66.1	66.2	66.8	66.9	67.8	67.9	63.3	63.8	53.8	54.1	59.5	59.6	59.3	59.6
Mean Income	48.4	44.4**	44.6	44.4	48.0	44.3**	48.3	44.9**	52.3	44.8**	49.5	45.0**	47.1	44.4**
Mean Population Density	4.44	4.27	4.65	4.44**	4.43	4.46	4.51	4.40	4.18	4.49	4.49	4.44	4.27	4.49
Mean % Dur. < 10 yrs.	48.7	50.5	49.5	50.3**	48.0	50.3**	47.4	50.2**	47.9	50.5**	47.8	50.3**	48.4	50.6**
% Near Haz. Waste Site	2.21	5.17	4.74	5.94**	4.55	5.77	2.24	5.26**	2.18	4.91**	4.64	5.49	3.98	5.73
% Near TRI Facility	2.94	5.17	5.15	5.16	3.98	4.94	5.16	4.83	3.27	4.68	5.01	4.50	3.98	4.62

**Statistically significant difference, $\alpha = .05$.

Variable Definitions for Table 4.1 and Table 4.2 (for block group of residence at date of diagnosis for cases and date of death for controls):
***Ecological variables from the 1990 U.S. Census*:**
Mean Income: Mean value of median income levels of block group of residence, expressed in thousands.
Mean Population Density: Population per square mile in the block group of residence, expressed in thousands.
Mean % Duration < 10 years: Mean value of percent of households in block group of residence with fewer than ten years at the current address.
Individual-level variables from study data:
Mean age: Mean age at diagnosis for cases and mean age at death for controls.
% Near Hazardous Waste site: Percent of study subjects residing within 1500 feet of a hazardous waste site (excluding sites classified as off-gassing landfills) listed in the Inactive Hazardous Waste Site Registry as of December 1992.
% Near TRI Facility: Percent of study subjects residing within ½ mile of an industrial facility reporting emissions to the Toxic Release Inventory in 1989.

Table 4.3
Evaluation of Potential Confounders: Comparison of Female Exposed vs Unexposed

	Liver		Lung		Bladder		Kidney		Brain		NH Lymphoma		Leukemia	
	Exp.	Unexp.	Exp.	Unexp.	Exp.	Unexp.	Exp.	Unexp.	Exp.	Unexp.	Exp.	Unexp.	Exp.	Unexp.
N	2	453	24	4516	13	2253	6	1797	6	1383	13	2742	10	1900
Mean Age	75.5	68.4	66.8	65.8	65.1	69.2	47.2	64.1**	32.5	56.0**	56.9	63.5	53.1	61.3
Mean Income	52.7	42.9	47.1	44.0	45.1	43.3	44.1	43.2	43.0	43.6	47.0	43.5	43.0	42.9
Mean Population Density	5.67	4.58	4.87	4.56	5.76	4.71	3.96	4.66	3.31	4.61	4.47	4.51	4.08	4.60
Mean % Blue Collar	5.5	11.6	9.54	11.1**	10.6	11.2	9.00	11.3	9.00	11.4	8.5	11.2	9.4	11.5
Mean % < H.S. Educ.	16.5	20.2	19.9	19.5	22.9	19.8	20.5	19.9	19.0	19.9	17.0	20.1	18.0	20.1
Mean % Dur. < 10 yrs.	35.5	51.6	41.0	50.5**	42.2	51.0**	47.7	50.7	47.7	51.1	43.4	50.5**	45.4	51.0
% Near haz. waste site	50.0	5.0**	66.7	5.2**	61.5	5.6**	50.0	5.5**	50.0	5.1**	69.2	5.3**	30.0	5.4**
% Near TRI facility	0	4.4**	0	4.6**	0	4.1**	0	4.3**	0	4.1**	0	4.4**	0	4.3**

Table 4.4
Evaluation of Potential Confounders: Comparison of Male Exposed vs Unexposed

	Liver		Lung		Bladder		Kidney		Brain		NH Lymphoma		Leukemia	
	Exp.	Unexp.	Exp.	Unexp.	Exp.	Unexp.	Exp.	Unexp.	Exp.	Unexp.	Exp.	Unexp.	Exp.	Unexp.
N	3	771	28	7809	20	5992	10	2529	8	1550	12	3059	14	2404
Mean Age	57.3	66.2	65.1	66.9	64.1	67.8	58.2	63.7	47.4	54.1	52.3	59.6	54.4	59.6
Mean Income	36.8	45.1	47.3	44.5	49.6	45.0	48.6	45.5	41.8	46.2	47.0	45.8	51.4	44.8
Mean Population Density	2.87	4.31	2.98	4.52**	2.53	4.46**	2.26	4.43**	1.70	4.45**	2.10	4.46**	2.13	4.46**
Mean % Blue Collar	11.7	10.9	9.6	11.1**	9.0	11.0**	9.2	10.9	10.4	10.9	9.5	10.9	9.7	11.1
Mean % < H.S. Educ.	23.3	19.1	16.7	19.2	16.0	19.0	15.8	19.0	19.1	18.7	16.8	18.9	16.5	19.2
Mean % Dur. < 10 yrs.	56.7	50.1	46.9	50.0	48.6	49.9	49.9	49.8	55.4	50.0	51.3	49.8	50.9	50.2
% Near Haz. Waste Site	66.7	4.4**	42.9	5.4**	55.0	5.4**	50.0	4.5**	62.5	4.1**	58.3	5.1**	50.0	5.2**
% Near TRI facility	0	4.8**	0	5.2**	0	4.8**	0	4.9**	0	4.4**	0	4.6**	0	4.5**

**Statistically significant difference, $\alpha = .05$.

Variable Definitions for Tables 4.3 and 4.4 (for block group of residence at date of diagnosis for cases and date of death for controls)::
Ecological variables from the 1990 U.S. Census:
Mean Income: Mean value of median income levels of block group of residence.
Mean Population Density: Population per square mile in the block group of residence, expressed in thousands.
Mean % Blue Collar: Mean of block group value for percent of employed persons who are in the category labeled, "operators, fabricators, and laborers."
Mean % < High School Education: Mean of block group value for percent of adults who did not complete high school.
Mean % Duration < 10 years: Mean value of percent of households in block group of residence with fewer than ten years at the current address.
Individual-level variables from study data:
Mean age: Mean age at diagnosis for cases and mean age at death for controls.
% Near Hazardous Waste site: Percent of study subjects residing within 1500 feet of a hazardous waste site (excluding sites classified as off-gassing landfills) listed in the Inactive Hazardous Waste Site Registry as of December 1992.
% Near TRI Facility: Percent of study subjects residing within ½ mile of an industrial facility reporting emissions to the Toxic Release Inventory in 1989.

Table 4.5
Evaluation of Potential Confounders: Seven Cancers, Males and Females

	Males		Females	Males		Females		
	Cases	Controls	Cases	Controls	Exp.	Unexp.	Exp.	Unexp.
N	5598	5789	3422	3380	39	11348	46	6756
Mean Age	64.7	64.5	64.4	62.4	63.2	64.6	61.9	63.4
Mean Income	46.7	44.4**	46.7	42.8**	50.5	45.5	46.4	44.8
Mean Population Density	4.52	4.48	4.49	4.60	2.99	4.51**	4.54	4.54
Mean % Blue Collar	10.5	11.2**	10.3	11.5**	9.38	10.9	9.48	10.9
Mean % < H.S. Educ.	18.5	19.3**	18.2	20.1**	16.4	18.9	19.5	19.1
Mean % Dur. < 10 yrs.	48.7	50.4**	48.9	51.1**	46.4	49.5	40.3	50.1**
% Near Haz. Waste Site	4.25	5.82**	3.59	6.36**	43.6	4.92**	47.8	4.68**
% Near TRI facility	4.68	4.96	3.19	4.91**	0	4.84**	0	4.07**

*Population is expressed in thousands.
**Statistically significant difference, $\alpha = .05$.

<u>Variable Definitions for Table 4.5 (for block group of residence at date of diagnosis for cases and date of death for controls):</u>:
<u>Ecological variables from the 1990 U.S. Census</u>:
Mean Income: Mean value of median income levels of block group of residence.
Mean Population Density: Population per square mile in the block group of residence, expressed in thousands.
Mean % Blue Collar: Mean of block group value for percent of employed persons who are in the category labeled, "operators, fabricators, and laborers."
Mean % < High School Education: Mean of block group value for percent of adults who did not complete high school.
Mean % Duration < 10 years: Mean value of percent of households in block group of residence with fewer than ten years at the current address.
<u>Individual-level variables from study data</u>:
Mean age: Mean age at diagnosis for cases and mean age at death for controls.
% Near Hazardous Waste site: Percent of study subjects residing within 1500 feet of a hazardous waste site (excluding sites classified as off-gassing landfills) listed in the Inactive Hazardous Waste Site Registry as of December 1992.
% Near TRI Facility: Percent of study subjects residing within ½ mile of an industrial facility reporting emissions to the Toxic Release Inventory in 1989.

Table 4.6
Evaluation of Potential Confounders: Comparison between Nassau-Suffolk and Upstate: Seven Cancers in Females

	Nassau-Suffolk		Upstate	Nassau-Suffolk		Upstate		
	Case	Control	Case	Control	Exp.	Unexp.	Exp.	Unexp.
N	1658	1412	1764	1968	36	3034	10	3722
Mean Age	63.3	61.9	65.4	62.8	63.5	62.6	56.3	64.0
Mean Income	56.2	54.2**	37.8	34.6**	50.0	55.4**	33.5	36.1
Mean Population Density	5.21	5.06	3.80	4.28**	5.19	5.14	2.19	4.06
Mean % Blue Collar	8.21	8.84**	12.3	13.5**	8.44	8.50	13.2	12.9
Mean % < H.S. Educ.	15.7	16.5**	20.6	22.7**	19.3	16.0**	20.2	21.7
Mean % Dur. < 10 yrs.	42.6	45.1**	54.8	55.5**	36.0	43.8**	56.0	55.1
% Near Haz. Waste Site	3.74	5.31**	3.46	7.11**	52.8	3.89**	30.0	5.32**
% Near TRI facility	1.93	3.12**	4.37	6.20**	0	2.50**	0.35**	
% in Landfill Buffer	1.39	0.92	0.34	0.20	NA	NA	NA	NA

Table 4.7
Evaluation of Potential Confounders: Comparison of Nassau-Suffolk and Upstate: Seven Cancers in Males

	Nassau-Suffolk		Upstate	Nassau-Suffolk		Upstate		
	Case	Control	Case	Control	Exp.	Unexp.	Exp.	Unexp.
N	2662	2509	2936	3280	26	5145	13	6203
Mean Age	64.2	63.7	65.2	65.1	65.4	64.0	58.8	65.2
Mean Income	56.5	55.5**	37.7	35.8**	54.0	56.0	43.4	36.7
Mean Population Density	5.32	5.06**	3.80	4.04**	3.44	5.20**	2.10	3.93
Mean % Blue Collar	8.22	8.56**	12.7	13.2**	8.35	8.39	11.5	12.9
Mean % < H.S. Educ.	15.6	16.0	21.0	21.9**	15.3	15.8	18.7	21.5
Mean % Dur. < 10 yrs.	42.7	44.4	54.2	54.9**	42.3	43.5	54.5	54.5
% Near Haz. Waste Site	3.68	4.78**	4.77	6.62**	53.8	4.00**	23.1	5.71**
% Near TRI facility	3.01	2.99	6.20	6.46	0	3.01**	0	6.35**
% in Landfill buffer	0.49	0.52	0.24	0.18	NA	NA	NA	NA

**Statistically significant difference, $\alpha = .05$.

Variable Definitions for Tables 4.6 and 4.7 (for block group of residence at date of diagnosis for cases and date of death for controls)::
***Ecological variables from the 1990 U.S. Census*:**
Mean Income: Mean value of median income levels of block group of residence.
Mean Population Density: Population per square mile in the block group of residence, expressed in thousands.
Mean % Blue Collar: Mean of block group value for percent of employed persons who are in the category labeled, "operators, fabricators, and laborers."
Mean % < High School Graduate: Mean of block group value for percent of adults who did not complete high school.
Mean % Duration < 10 years: Mean value of percent of households in block group of residence with fewer than ten years at the current address.
Individual-level variables from study data:
Mean age: Mean age at diagnosis for cases and mean age at death for controls.
% Near Hazardous Waste site: Percent of study subjects residing within 1500 feet of a hazardous waste site (excluding sites classified as off-gassing landfills) listed in the Inactive Hazardous Waste Site Registry as of December 1992.
% Near TRI Facility: Percent of study subjects residing within ½ mile of an industrial facility reporting emissions to the Toxic Release Inventory in 1989.
% in Landfill buffer: Percent of study subjects residing in the landfill potential exposure areas.

Table 4.8
Distribution of Cases and Controls and Crude Odds Ratios by Residential Location in Off-Gassing Landfill Potential Exposure Areas (Buffers) for Seven Cancers in Females

	Cases	Controls	Cases Exposed N (%)	Controls Exposed N (%)	Crude Odds Ratio	95% Confidence Interval
Liver	80	375	1 (1.25)	1 (0.27)	4.73	0.29 - 76.50
Lung	1570	2970	10 (0.64)	14 (0.47)	1.35	0.60 - 3.05
Bladder	397	1869	6 (1.51)	7 (0.37)	4.08	1.36 - 12.21**
Kidney	316	1487	2 (0.63)	4 (0.27)	2.36	0.43 - 12.95
Brain	243	1146	2 (0.82)	4 (0.35)	2.37	0.43 - 13.01
N-H Lymphoma	481	2274	3 (0.62)	10 (0.44)	1.42	0.39 - 5.18
Leukemia	335	1575	5 (1.49)	5 (0.32)	4.76	1.37 - 16.53**

**Statistically significantly differs from 1.00, $\alpha = .05$.

Table 4.9
Distribution of Cases and Controls and Crude Odds Ratios by Residential Location in Off-Gassing Landfill Potential Exposure Areas (Buffers) for Seven Cancers in Males

	Cases	Controls	Cases Exposed N (%)	Controls Exposed N (%)	Crude Odds Ratio	95% Confidence Interval
Liver	136	638	0 (0.00)	3 (0.47)	0.00	0.00 - 11.39
Lung	2721	5116	12 (0.44)	16 (0.31)	1.41	0.67 - 2.99
Bladder	1054	4958	4 (0.38)	16 (0.32)	1.18	0.39 - 3.53
Kidney	446	2093	0 (0.00)	10 (0.48)	0.00	0.00 - 2.09
Brain	275	1283	0 (0.00)	8 (0.62)	0.00	0.00 - 2.73
N-H Lymphoma	539	2532	0 (0.00)	12 (0.47)	0.00	0.00 - 1.69
Leukemia	423	1991	4 (0.94)	10 (0.50)	1.87	0.59 - 6.00

Table 4.10
Distribution of Cases and Controls and Crude Odds Ratios
by Residential Location within 500 feet of the Off-Gassing Landfill Potential Exposure Areas (Buffers)
for Seven Cancers in Females
(Cases and controls located within the off-gassing landfill buffers are excluded from these calculations)

	Cases	Controls	Cases Exposed N (%)	Controls Exposed N (%)	Crude Odds Ratio	95% Confidence Interval
Liver	79	374	1 (1.27)	6 (1.60)	0.79	0.09 - 6.62
Lung	1560	2956	25 (1.60)	50 (1.69)	0.95	0.58 - 1.54
Bladder	391	1862	7 (1.79)	32 (1.72)	1.04	0.46 - 2.38
Kidney	314	1483	4 (1.27)	20 (1.35)	0.94	0.32 - 2.78
Brain	241	1142	2 (0.83)	8 (0.70)	1.19	0.25 - 5.62
N-H Lymphoma	478	2264	7 (1.46)	36 (1.59)	0.92	0.41 - 2.08
Leukemia	330	1570	5 (1.52)	24 (1.53)	0.99	0.38 - 2.62

Table 4.11
Distribution of Cases and Controls and Crude Odds Ratios
by Residential Location within 500 Feet of Off-Gassing Landfill Potential Exposure Areas (Buffers)
for Seven Cancers in Males
(Cases and controls located within the off-gassing landfill buffers are excluded from these calculations)

	Cases	Controls	Cases Exposed N (%)	Controls Exposed N (%)	Crude Odds Ratio	95% Confidence Interval
Liver	136	635	1 (0.74)	8 (1.26)	0.58	0.07 - 4.68
Lung	2709	5100	33 (1.22)	78 (1.53)	0.79	0.53 - 1.20
Bladder	1050	4942	16 (1.52)	74 (1.50)	1.02	0.59 - 1.76
Kidney	446	2083	6 (1.35)	28 (1.34)	1.00	0.41 - 2.43
Brain	275	1275	1 (0.36)	16 (1.25)	0.29	0.04 - 2.17
N-H Lymphoma	539	2520	9 (1.67)	32 (1.27)	1.32	0.63 - 2.78
Leukemia	423	1981	7 (1.65)	30 (1.51)	1.09	0.48 - 2.51

Table 4.12
Distribution of Cases and Controls and Crude Odds Ratios
by Residential Location within One Half Mile of a TRI Facility*
for Seven Cancers in Females

	Cases	Controls	Cases Exposed N (%)	Controls Exposed N (%)	Crude Odds Ratio	95% Confidence Interval
Liver	80	375	4 (5.00)	16 (4.27)	1.18	0.38 - 3.63
Lung	1570	2970	52 (3.31)	154 (5.19)	0.63	0.45 - 0.86**
Bladder	397	1869	7 (1.76)	85 (4.55)	0.38	0.17 - 0.82**
Kidney	316	1487	7 (2.22)	71 (4.77)	0.45	0.21 - 0.99**
Brain	243	1146	9 (3.70)	48 (4.19)	0.88	0.43 - 1.82
N-H Lymphoma	481	2274	14 (2.91)	106 (4.66)	0.61	0.35 - 1.08
Leukemia	335	1575	16 (4.78)	66 (4.19)	1.15	0.65 - 2.01

**Statistically significantly differs from 1.00, $\alpha = .05$.

Table 4.13
Distribution of Cases and Controls and Crude Odds Ratios
by Residential Location within One Half Mile of a TRI Facility*
for Seven Cancers in Males

	Cases	Controls	Cases Exposed N (%)	Controls Exposed N (%)	Crude Odds Ratio	95% Confidence Interval
Liver	136	638	4 (2.94)	33 (5.17)	0.56	0.19 - 1.60
Lung	2721	5116	140 (5.15)	264 (5.16)	1.00	0.81 - 1.23
Bladder	1054	4958	42 (3.98)	245 (4.94)	0.80	0.57 - 1.12
Kidney	446	2093	23 (5.16)	101 (4.83)	1.07	0.67 - 1.71
Brain	275	1283	9 (3.27)	60 (4.68)	0.69	0.34 - 1.41
N-H Lymphoma	539	2532	27 (5.01)	114 (4.50)	1.12	0.73 - 1.72
Leukemia	423	1991	17 (3.98)	92 (4.62)	0.86	0.50 - 1.45

*Residence within ½ mile of an industrial facility reporting emissions to the Toxic Release Inventory in 1989.

Table 4.14
Distribution of Cases and Controls and Crude Odds Ratios by Residential Location within 1500 Feet of a Hazardous Waste Site* for Seven Cancers in Females

	Cases	Controls	Cases Exposed N (%)	Controls Exposed N (%)	Crude Odds Ratio	95% Confidence Interval
Liver	80	375	5 (6.25)	24 (6.40)	0.97	0.36 - 2.64
Lung	1570	2970	92 (5.86)	214 (7.21)	0.80	0.62 - 1.03
Bladder	397	1869	28 (7.05)	131 (7.01)	1.01	0.66 - 1.54
Kidney	316	1487	20 (6.33)	96 (6.46)	0.98	0.59 - 1.61
Brain	243	1146	10 (4.12)	73 (6.37)	0.63	0.32 - 1.24
N-H Lymphoma	481	2274	23 (4.78)	155 (6.82)	0.69	0.44 - 1.08
Leukemia	335	1575	24 (7.16)	103 (6.54)	1.10	0.70 - 1.75

Table 4.15
Distribution of Cases and Controls and Crude Odds Ratios by Residential Location within 1500 Feet of a Hazardous Waste Site* for Seven Cancers in Males

	Cases	Controls	Cases Exposed N (%)	Controls Exposed N (%)	Crude Odds Ratio	95% Confidence Interval
Liver	136	638	4 (2.94)	38 (5.96)	0.48	0.17 - 1.36
Lung	2721	5116	178 (6.54)	340 (6.65)	0.98	0.81 - 1.19
Bladder	1054	4958	68 (6.45)	321 (6.47)	1.00	0.76 - 1.31
Kidney	446	2093	18 (4.04)	127 (6.07)	0.65	0.39 - 1.08
Brain	275	1283	9 (3.27)	76 (5.92)	0.54	0.27 - 1.09
Lymphoma	539	2532	33 (6.12)	159 (6.28)	0.97	0.66 - 1.43
Leukemia	423	1991	28 (6.56)	129 (6.48)	1.01	0.66 - 1.55

*Residence within 1500 feet of a hazardous waste site (including sites classified as off-gassing landfills) listed in the Inactive Hazardous Waste Site Registry as of December 1992.

Table 4.16
Crude and Adjusted Odds Ratios for Residence within the Off-Gassing Landfill Buffers For Cancers in Females and Cancers in Males

	Cancers in Females					Cancers in Males#				
	Crude		Adjusted		Variables	Crude		Adjusted		Variables
Cancer	OR	95% CI	OR	95% CI	Included	OR	95%CI	OR	95% CI	Included
Liver	4.73	0.29-76.5	7.90	0.41-152	6					
Lung	1.35	0.60-3.05	1.71	0.73-4.03	3,4,8,10	1.41	0.67-2.99	1.57	0.74-3.34	3,6
Bladder	4.08**	1.36-12.2	5.52**	1.67-18.2	1,2,3,4,5,6,9,10	1.18	0.39-3.53	1.30	0.42-3.97	4,5,6,7,10
Kidney	2.36	0.43-12.9	2.25	0.41-12.4	2,4					
Brain	2.37	0.43-13.0	3.29	0.57-19.1	3, 4					
NH Lymphoma	1.42	0.39-5.18	2.03	0.52-7.85	2,3,4,5,9,10					
Leukemia	4.76**	1.37-16.5	5.13**	1.45-18.1	3,4,5	1.87	0.59-6.00	2.16	0.65-7.14	3,4,5

For liver, kidney, brain, and non-Hodgkin's lymphoma in males, there were no exposed cases. Further analysis for these cancers is shown in appendix Table B-3.
** Statistically significant, $\alpha = .05$

	Values	Definition
Off-gassing landfill buffer	0,1	1=Residence within off-gassing landfill buffer (usually 250 feet) at diagnosis (cases) or death (controls)
1. <=500 ft from buffer	0,1	1=Residence within the 500 feet adjacent to the landfill buffer
2. <=1/2 mile of TRI facility	0,1	1=Residence within ½ mile of a manufacturing facility reporting TRI releases from 1988-1993
3. <= 1500 ft from other hws	0,1	1=Residence within 1500 feet of listed inactive hazardous waste sites (other than the off-gassing landfills)
4. low income	0,1	1=Residence in a block group ranking among the lowest 20% for study subject's block group average household income.
5. low duration of residence	0,1	1=Residence in a block group in the highest decile for percentage of households with less than ten years at current address.
6. high population density	0,1	1=Residence in a block group in the highest decile of study subjects' block group population density.
7. hws*income	0-9	1-9=Residence within 1500 feet of a hazardous waste site, from 1-9=low to high block group income decile
8. hws*population	0-9	1-9=Residence within 1500 feet of a hazardous waste site, from 1-9=low to high population density decile
9. TRI*income	0-9	1-9=Residence within ½ mile of a TRI facility, from 1-9=low to high income decile
10. TRI*population	0-9	1-9=Residence within ½ mile of a TRI facility, from 1-9=low to high population density decile

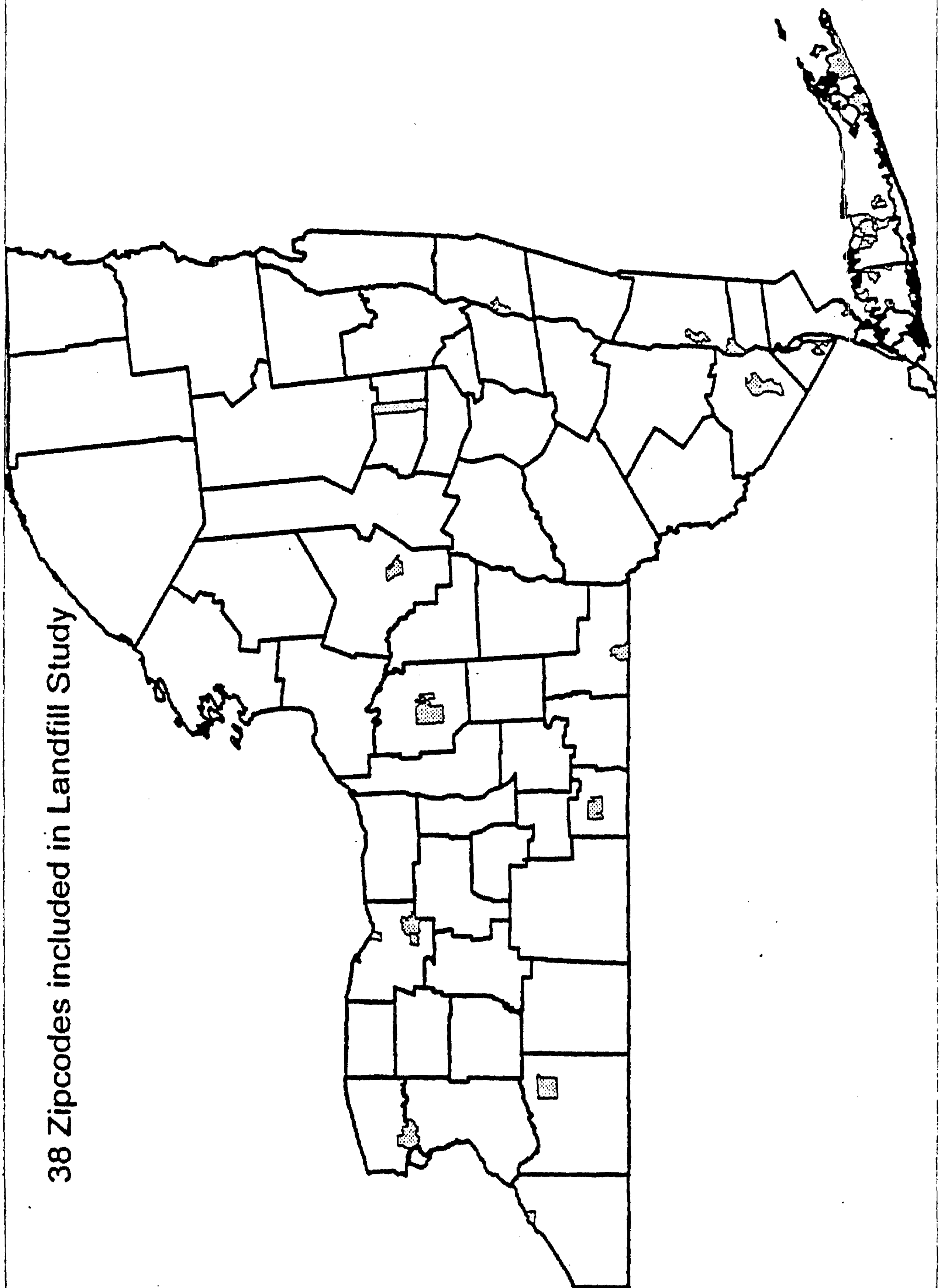
Table 5.1
Cause of Death of Female Controls

Cancer	Circu-tory	Respir-atory	Injury and Poisoning	Diges-tive	Endocrine, Nutritional, Metabolic, Immunity	All Other	Total
Liver	68.8	7.2	6.7	5.1	2.7	9.6	100.1
Lung	62.9	8.7	6.1	8.2	4.3	9.7	99.9
Bladder	65.5	9.1	5.4	7.2	3.8	9.0	100.0
Kidney	61.2	8.1	7.5	7.6	4.2	11.5	100.1
Brain	52.4	7.9	13.7	7.2	3.6	15.2	100.0
NH Lymphoma	59.1	8.3	9.8	7.6	3.7	11.3	99.8
Leukemia	57.2	7.6	10.7	6.9	3.6	13.8	99.8

Table 5.2
Cause of Death for Male Controls

Cancer	Circu-tory	Respir-atory	Injury and Poisoning	Diges-tive	Endocrine, Nutritional, Metabolic, Immunity	All Other	Total
Liver	68.8	9.2	6.0	5.0	3.3	7.6	99.9
Lung	67.9	10.3	5.0	6.1	3.5	7.3	100.1
Bladder	67.6	10.4	5.2	6.1	3.2	7.4	99.9
Kidney	65.9	9.4	6.8	6.1	3.1	8.5	99.8
Brain	55.7	7.7	16.9	6.2	2.6	10.8	99.9
NH Lymphoma	60.8	8.4	13.2	5.8	3.0	8.8	100.0
Leukemia	57.4	9.6	13.2	5.2	2.6	11.9	99.9

FIGURE 1



38 Zipcodes included in Landfill Study

APPENDIX A

METHANE LANDFILL DATA INVENTORY

SITE NAME______________________ SITE COUNTY_______________

REVIEWER______________________

- -

1. DATE OF REVIEW __ __/__ __/__ __

2. SITE NUM __ __ __ __ __ __ - __ 3. SITE CLASS __ __
(Enter 1-4 for A-D
if Applicable, Otherwise
Enter 0.)

4. DELISTED? Y__ N__ U__

5. LANDFILL TYPE: Y=YES, N=NO, U=UNKNOWN

Owner	Facility	Waste Type
____Municipal	___Landfill	____Residential
____Private	___Open Dump	____Municipal
____County		____Commercial
____Other		____Industrial
		____Agricultural
		____C and D
		____Other (i.e., asbestos, pharmaceutics)
		___Hazardous Waste

6. POTABLE WATER SUPPLY

Is surface water used a water supply for any residents within one mile of the site? Y__ N__ U__

Is groundwater used as a water supply for any residents within one mile of the site? Y__ N__ U__

If groundwater is used, are there any private wells located within one mile of the site? Y__ N__ U__

7. LANDFILL SIZE

APPROXIMATE SIZE OF LANDFILL __ __ __ __.__ ACRES
NUMBER OF CELLS KNOWN? Y__N__
YEARS OF OPERATION OF EACH CELL KNOWN? Y__N__
IF YES, CELL 1 OPERATED 19__ __TO 19__ __ (99 = UNKNOWN)
CELL 1 SIZE IN ACRES __ __ __.__ (U = UNKNOWN, NA=NOT APPLICABLE)
CELL 2 OPERATED 19__ __TO 19__ __ (99 = UNKNOWN)
CELL 2 SIZE IN ACRES __ __ __.__ (U = UNKNOWN, NA=NOT APPLICABLE)

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CELL 3 OPERATED 19__ __ TO 19__ __ (99 = UNKNOWN)
CELL 3 SIZE IN ACRES __ __ __.__ (U =UNKNOWN, NA=NOT APPLICABLE)
CELL 4 OPERATED 19__ __ TO 19__ __ (99 = UNKNOWN)
CELL 4 SIZE IN ACRES __ __ __.__ (U=UNKNOWN,NA=NOT APPLICABLE)
CELL 5 OPERATED 19__ __ TO 19__ __ (99 = UNKNOWN)
CELL 5 SIZE IN ACRES __ __ __.__ (U=UNKNOWN,NA=NOT APPLICABLE)

QUANTITY AND/OR TYPE OF WASTE DISPOSED FOR ANY OR ALL YEARS KNOWN? Y__N__U__

IF YES:
RECORD NUMBER OF TONS OF EACH TYPE OF WASTE RECEIVED PER YEAR

8. SITE ACTIVITY

ENTER YEAR THAT LANDFILL WAS OPENED: 19__ __ (99=UNKNOWN)
DID LANDFILL ACCEPT INDUSTRIAL WASTE? Y___N___U___
IF YES ENTER YEARS 19___ TO 19___ (99 = UNKNOWN)
DID LANDFILL ACCEPT MUNICIPAL WASTE? Y___N___U___
IF YES ENTER YEARS 19___ TO 19___ (99=UNKNOWN)
DID LANDFILL ACCEPT RESIDENTIAL WASTE? Y__N__U___
IF YES ENTER YEARS 19___ TO 19___
DID LANDFILL ACCEPT AGRICULTURAL WASTE? Y__N__U__
IF YES ENTER YEARS 19___ TO 19___
DID LANDFILL ACCEPT COMMERCIAL WASTE? Y__N__U__
IF YES ENTER YEARS 19___ TO 19___
DID LANDFILL ACCEPT C AND D WASTE? Y__N__U__
IF YES ENTER YEARS 19__ __ TO 19__ __

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9. SITE CONSTRUCTION, OPERATION AND CLOSURE

IS THE LANDFILL CLOSED? Y__N__U__
IF YES, WHEN WAS THE LANDFILL CLOSED? 19__ __ (99=UNKNOWN)
IS THE LANDFILL LINED? Y__N__U__
IF YES, TYPE OF LINER(S):
__DOUBLE COMPOSITE LINER
__COMPOSITE LINER
__OTHER
IS (WAS THERE) A LEACHATE COLLECTION SYSTEM? Y__N__U__
IF YES, DATE OPERATION BEGAN 19 __ __ (99=UNKNOWN)
IS (WAS THERE) A GAS COLLECTION)? Y__N__U__
IF YES, DATE OPERATION BEGAN 19 __ __ (99=UNKNOWN)
IS (WAS) THE LANDFILL COVERED? Y__N__U__
COVER MATERIAL= SOIL? Y__N__U__
IF NO, TYPE OF COVER MATERIAL______________________________
IS (WAS) THE LANDFILL CAPPED? Y__N__U__
DATE CAPPING BEGAN 19__ __ (99 = UNKNOWN)
DATE CAPPING COMPLETED 19 __ __ (99 = UNKNOWN)
NUMBER OF ACRES CAPPED__ __ __ __. __ (99 FOR UNKNOWN)

10. TYPE OF REPORT(S) IN FILE
Y=YES N=NO U=UNKNOWN (OR QUESTIONABLE) P=PENDING

a.__ PHASE 1

b.__ DOH SITE INSPECTION & HEPRM

c.__ OTHER INSPECTION/SAMPLING <PHASE II (EPA, USGS, DEC, COUNTY)

d.__ PHASE 2

e.__ REMEDIAL INVESTIGATION

f.__ FEASIBILITY STUDY

g.__ OTHER REPORT INCLUDING SAMPLING RESULTS:____________________

h.__ RISK ASSESSMENT

i.__ LANDFILL CLOSURE REPORT

11. ENVIRONMENTAL SAMPLING DATA INVENTORY
Y=YES N=NO U=UNKNOWN (OR QUESTIONABLE)

	On-Site	Off-Site
a. Soil sample results (surface soil, shallow soil borings or waste/sludge piles).	____	____
b. Surface water sample results (waste lagoons/ponds, drainage ditches or streams).	____	____
c. Groundwater sample results (monitoring wells, private wells or public wells).	____	____
d. Ambient air samples/monitoring	____	____
e. Indoor air samples/monitoring (facility, homes)	____	____
f. Soil gas survey results/samples	____	____
g. Leachate samples	____	____

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Appendix B
Logistic Regression Modeling Results

The model building process is presented in detail in Tables B-1, B-2, and B-3 for each cancer site to show how the inclusion of groups of covariates affects the off-gassing landfill exposure odds ratio. This makes it possible to see if the parameter estimates for the control variables are performing as expected in the models. The univariate, or unadjusted, odds ratios are shown along with three other models. In the second model, the three environmental variables based on residential proximity are added. A second off-gassing landfill exposure variable is added which indicates whether the residence at date of cancer diagnosis for cases, or date of death for controls, was within 500 feet of the landfill exposure buffer. Residence within one-half mile of a TRI facility and residence within 1500 feet of other hazardous waste sites are also included in Model 2.

In Model 3, the three demographic variables from census block groups are added to the models. These include the variables indicating low income, short duration of residence, and high population density. The fourth model includes environmental-demographic interactions. Only in the fourth model are variables removed from the model based on their significance level. Model 4 shows the estimated parameters and statistics for the model which includes only those variables which met the criterion for inclusion and remaining in the model of p-value less than or equal to .20. Confidence intervals and probability (p) values are presented for each estimated odds ratio. The p-values associated with the goodness-of-fit statistic (-2 Log likelihood) are shown for each model as a tool for interpreting whether the addition of covariates improves the models' prediction of case status.

Table B-1 presents the analyses for the seven cancers in females. Table B-2 shows the three cancers in males for which there were exposed cases. Table B-3 presents the analyses conducted for the four cancers that had no cases residing in the off-gassing landfill potential exposure areas. These cancers are presented here so that the role of the covariates can be examined. The primary exposure variable is not assessed in these models. Since there were no exposed cases for male non-Hodgkin's lymphoma or liver, kidney, or brain cancer, the odds ratios are 0.00 for these cancers. In order to evaluate models including the covariates, the broader exposure criterion of living in the landfill buffer or within 500 feet of the buffer is used in these four models.

Model 2: Other Environmental Variables

For all the cancer sites shown in Table B1 and Table B2, the second model which adjusted for the three potential environmental confounders and covariates produces higher odds ratios for the exposure variable being evaluated, residence within an off-gassing landfill buffer. The only landfill exposure odds ratios which are significant, however, are for bladder cancer in females and leukemia in females, the cancers for which the unadjusted odds ratios were also significantly elevated. The more distant potential landfill exposure variable (<=500 feet from buffer), is elevated, but not significantly, for all the cancers in females, and for bladder cancer and leukemia in males.

The control variables, however, which are included in order to adjust for potential harmful effects of TRI and hazardous waste sites, are showing some significant protective effects. As will be seen from the models described below, these geographic variables may be playing a role in these models as indicators of the socioeconomic differences between cases and controls. One or both of the TRI and other hazardous waste site potential exposure variables are statistically significantly less than one for non-Hodgkin's lymphoma, lung, bladder, and brain cancer in females, and lung and kidney cancer in males. (Tables B-1, B-2 and B-3) The TRI variable is statistically significantly below one for two cancers, lung and bladder cancer in females. The odds ratio estimates for the TRI potential exposure variable for the other cancers are not all below one. For residence near other (non-off-gassing) hazardous waste sites, however, all the odds ratio estimates are below one. These odds ratio estimates are statistically significant for six cancers (out of 14), lung, bladder, brain cancer, and non-Hodgkin's lymphoma in females and lung and kidney cancer in males.

Model 3: Demographic Variables

The addition of the demographic variables has no substantive effect on the off-gassing landfill odds ratios, which continue to be significantly elevated only for the two cancers in females, bladder cancer and leukemia. The demographic variables also have no substantive effect on the apparently protective effects of potential TRI and hazardous waste site exposures for several cancers, bladder cancer in females among them. Low income (among the lowest one-fifth of all study subjects in block group income) is statistically significantly protective for four out of seven cancers in females: lung, bladder, and kidney, and Non-Hodgkin's lymphoma. Low income is significantly protective against five out of seven cancers for men: bladder, kidney, brain, non-Hodgkin's lymphoma and leukemia in males. Short duration of residence (among the lowest one-tenth of all study subjects in percent of block group households with less than ten years' residence) is also statistically significantly protective against bladder cancer and in females, bladder and brain cancer in males. High population density appears as a statistically significant risk factor in Model 3 for only one cancer in females, bladder cancer, and one cancer in males, kidney cancer.

Model 4: Final Models including Interactions

Because of the statistical significance of the environmental and demographic variables in some of the models, particularly for bladder cancer in females, a fourth model including four interaction terms is also presented. The inclusion of these additional variables again has no substantive effect on the odds ratios for potential exposure to off-gassing landfills for bladder cancer in females and leukemia in females.

Inclusion of the interaction terms in Model 4 results in the TRI potential exposure variable no longer showing any statistically significant protective effects. A non-significant protective effect of potential TRI exposure is included in the final model for only one cancer, kidney cancer in females. The odds ratios for residence within one-half mile of a TRI facility now show significant elevations in Model 4 for bladder cancer and non-Hodgkin's lymphoma in females. This shift in the estimated effect of residence near TRI facilities appears to be related to controlling for interactions between TRI facilities and population density and TRI and income. For bladder cancer or non-Hodgkin's lymphoma, there appear to protective effects associated with living near a TRI facility and in a block group with relatively high population density, or living near a TRI facility and in a block group with relatively high income. In models including interactions, the protective effect of residing near hazardous waste sites (other than the off-gassing landfills) continues to produce odds ratios below 1.00 for several cancers. This apparently protective effect is statistically significant for non-Hodgkin's lymphoma, lung and bladder cancer in females, and lung and kidney cancer in males.

Cancers in Females

Liver Cancer in Females: The estimated elevated odds ratio for residence within the off-gassing landfill buffers increases from 4.73 (CI: 0.29-76.5, p = .273) in the unadjusted model to 7.90 (CI: 0.41-152) in the final model. These odds ratios remain statistically non-significant however. The rarity of liver cancer and the very small number of liver cancer cases in females residing in the study's off-gassing landfill buffers (two) result in a very wide confidence interval for the adjusted odds ratio. No variables achieve statistical significance in any of the four models. High population density and residence within the off-gassing landfill buffer met the criterion, α=.20, for remaining in the final model.

Lung Cancer in Females: For lung cancer in females, the adjusted odds ratios for residing in an off-gassing landfill potential exposure area are elevated, but not statistically significant in any of the models. The adjusted odds ratios are slightly higher than the unadjusted odds ratio, and the p-values for the overall model's goodness-of-fit are significant for Models 2, 3, and 4. While the odds ratio for potential landfill exposure in Model 2 is not significant, its estimated value is 2.00, with a confidence interval ranging from 0.86-4.67 and a p-value of .109.

The environmental variables added in Model 2 improve the model's ability to predict lung cancer status, but this is due to significant protective effects shown for living near a TRI site or hazardous waste site. In Models 3 and 4, living near a TRI site no longer produces a significant reduction in lung cancer risk, but residence near a hazardous waste site continues to show a statistically significant protective effect. Low income also shows statistically significant protective effects. High population density near hazardous waste sites shows a significantly elevated odds ratio. The final model also includes an interaction showing a protective effect of living near a TRI site in an area with high population density. The difficulty of interpreting the role of these covariates in the model limits the interpretation of the odds ratio for the off-gassing landfill exposure as well.

Bladder Cancer in Females: The logistic regression results for bladder cancer in females continue to show a statistically significantly elevated odds ratio for residing in the off-gassing landfill potential exposure area. The adjusted odds ratios for residence in an off-gassing landfill buffer are statistically significantly elevated in all three multiple logistic regression models. The adjusted odds ratios are higher than the unadjusted odds ratio and Models 3 and 4 produce lower p-values (better fit) for the goodness-of-fit statistic. In Model 4 the odds ratio for residence in the landfill potential exposure area is 5.52, with a confidence interval ranging from 1.67 to 18.2 ($p = .005$). Residence within the area within 500 feet of the potential exposure area produces a statistically non-significant, but elevated odds ratio of 2.00, with a confidence interval ranging from 0.81 to 4.91, $p = .132$.

High population density is a risk factor for bladder cancer in females in these models, with an odds ratio of 2.37 (CI: 1.72-3.27, $p = .0001$) in Model 4. Low income (OR = 0.64, CI: 0.47-0.87, $p = .004$), low duration of residence (OR = 0.48, CI: 0.30-0.77, $p = .003$) and living within 1500 feet of another hazardous waste site (OR=0.47, CI: 0.25-0.88) are all significantly protective in Model 4. Residence within ½ mile of a TRI facility shows a significantly elevated odds ratio (7.94, CI: 1.22-51.7, $p = .030$) in Model 4, while in Models 2 and 3, this variable produced a significantly lowered odds ratio. The reversal in effect of residence near a TRI facility is due to the inclusion of the interaction variable which accounts separately for high population density near TRI facilities. This variable shows a significantly decreased odds ratio for residing near TRI facilities where there is high population density.

High population density produces a larger odds ratio in the models for bladder cancer in females than for any other cancer. It is the only cancer in females for which this variable produces a statistically significantly elevated odds ratio. Despite the significant contributions of the control variables to the model, the odds ratio for the primary exposure variable, residence in an off-gassing landfill potential exposure area, remains elevated and statistically significant, and its magnitude increases from the univariate to the multivariate models.

Kidney Cancer in Females: For kidney cancer in females the modeling process produces improved prediction of case status in Models 3 and 4, due to the addition of the variable representing low income. Again, low income is significantly protective against a cancer diagnosis, with an odds ratio of 0.60, confidence interval, 0.44-0.83. While not statistically significant, residence near a TRI facility remained in the final model, suggesting a protective effect. The elevated adjusted odds ratio for residence in the off-gassing landfill buffer in Model 3 is slightly higher, and in Model 4 is slightly lower, than the elevated unadjusted odds ratio. The adjusted odds ratios for residence in the off-gassing landfill potential exposure area remain statistically non-significant.

Brain Cancer in Females: The logistic regression models' adjusted odds ratios remain statistically non-significant for the off-gassing landfill exposure variable for brain cancer in females. They remain elevated however and are larger (OR = 3.29, CI: 0.57-19.1, $p = .185$ in Model 4) than the unadjusted odds ratio (OR = 2.37, CI: 0.43-13.0, $p = .321$). The hazardous waste site variable is at the borderline of statistical significance, suggesting a protective effect in Model 4. Low income again shows a statistically significant protective effect.

Non-Hodgkin's Lymphoma in Females: The adjusted odds ratio for residence in the off-gassing landfill potential exposure area (OR=2.03, CI: 0.52-7.85, p = .306 in Model 4) shows a slight increase over the unadjusted odds ratio, but this odds ratio is not statistically significantly elevated.

The variable for low income produces a statistically significantly reduced odds ratio in Model 4. As seen above in the models for bladder cancer in females, the odds ratio for residence near a TRI facility becomes elevated and statistically significant in Model 4 (OR=7.62, CI: 1.85-31.5, p = .005). Also similar to bladder cancer in females, high population density for subjects residing near TRI facilities is statistically significantly protective against a cancer diagnosis (OR=0.74, CI: 0.58-0.93, p = .011). For non-Hodgkin's lymphoma in females, high income for subjects residing near TRI facilities also suggests a protective effect against a cancer diagnosis (OR= 0.70, CI: 0.49-1.00, p = .05). Also similar to the models for bladder cancer, there is a statistically significant protective effect shown for living near hazardous waste sites.

Leukemia in Females: For leukemia in females the modeling results were somewhat different from the cancers described above. In contrast to the other modeling results, the addition of other environmental and demographic variables did not substantially improve the model's ability to predict leukemia case status. The adjusted odds ratios for potential off-gassing landfill exposure for leukemia in females in Models 2, 3 and 4 were again statistically significant and elevated. The adjusted odds ratios are slightly higher than the unadjusted odds ratio. In Model 4, the odds ratio for the landfill buffer is 5.13, with a confidence interval ranging from 1.45 to 18.1 (p = .011).

None of the environmental or demographic variables show statistically significant effects in the model. While not statistically significant, the odds ratio estimates for residence near a hazardous waste site, low income, and low duration of residence are again below 1.00, as in models for the other cancers.

Cancers in Males

Lung Cancer in Males: The multiple logistic regression models slightly improve the prediction of lung cancer in males, largely due to the hazardous waste site variable which shows a statistically significant protective effect against lung cancer in males (OR=0.77, CI: 0.62-0.96, p = .017). The odds ratio for residence in the off-gassing landfill buffers increases very slightly from the unadjusted estimate of 1.41 (CI: 0.67-2.99, p = .367) to the Model 4 adjusted estimate of 1.57 (CI: 0.74-3.34, p = .242), but remains statistically non-significant. Because smoking is a strong risk factor for lung cancer as well as respiratory disease which is the cause of death for a large proportion of the male controls in this study, the findings for lung cancer may be particularly difficult to interpret due to the use of deceased controls. High population density remained in the final model, with an elevated odds ratio (1.15 CI:0.99-1.34, p=.075) that is close to being statistically significant.

Bladder Cancer in Males: The addition of other environmental and demographic variables in models for bladder cancer in males produces model parameters showing slightly higher odds ratios for the adjusted off-gassing landfill buffer potential exposure variable (OR = 1.30, CI: 0.42-3.97, p = .651) than for the unadjusted odds ratio (OR = 1.18, CI: 0.39-3.53, p = .771) and increasingly better fit to the data. The statistically significant protective effects of residing in a low income block group (OR = 0.70, CI: 0.58-0.84, p = .0001) and short duration of residence block group (OR = 0.71, CI: 0.53-0.95, p = .020) contribute to the models' improvement. High population density, while not statistically significant, also suggests a positive effect on the risk for bladder cancer in the two final models (OR = 1.20, CI: 0.96-1.51, p = .107 in Model 4).

Leukemia in Males: The odds ratio for residence in the off-gassing landfill buffer increases in the final model to 2.16 (CI: 0.65-7.28, p = .199) from the unadjusted value of 1.87 (CI: 0.59-6.00, p = .291), but remains statistically non-significant. Low income is again statistically significantly protective in the model, and low duration of residence and residence near another hazardous waste site remain in the final model with non-significant protective effects.

For the other cancers in males, liver, kidney, and brain cancer, and non-Hodgkin's lymphoma, there were no cancer cases who resided at diagnosis in the off-gassing landfill potential exposure areas. This study therefore provides no evidence that residence within the off-gassing landfill potential exposure areas poses any increased risk for these cancers in males. In order to look further at how the other environmental and demographic variables relate to these cancers in males, models were estimated that used a more general potential exposure classification. In order to avoid modeling problems associated with not having any exposed cases, the exposure variables, residence with the off-gassing landfill buffer and within 500 feet of the buffer, were combined. Based on the univariate results, it was not expected that this exposure variable would show any significant or elevated odds ratios, but these models might provide clues about why the study population included no exposed cases for these cancers.

Liver cancer in males was the only one of the four cancers that did not include the variable for low income in the final model. For brain cancer (OR=0.54, CI: 0.36-0.80, p=.002) and non-Hodgkin's lymphoma (OR=0.62, CI; 0.48-0.81, p=.0005) the apparently protective effect for living in a low income block group was statistically significant. For kidney cancer (OR=0.81, CI: 0.61-1.07, p=.132) the protective effect of low income was not statistically significant. The importance of low income as an apparently protective factor in these analyses may be part of an explanation of why the study population included no male cases classified as exposed for these four cancers. People with lower incomes and less access to comprehensive health care may be less likely to be accurately diagnosed with cancer. If this effect were slightly stronger for men, who are less likely than women to seek health care, then this might explain why fewer male than female cases were found in the potential exposure areas. The number of cases residing in the off-gassing landfill potential exposure areas is already quite small for all of the cancers, ranging from zero to twelve, with only lung cancer among males and lung cancer among females having more than six exposed cases.

Summary

The inclusion of environmental and demographic covariates and potential confounders increased the magnitude of the odds ratios for the two cancers in females, bladder cancer and leukemia, which had shown statistically significantly elevated risk in the univariate analyses. The significant covariates presented in detail in this Appendix suggest various interpretations but were included in the models and examined in order to see how they affected the off-gassing landfill exposure odds ratios. Particularly because the demographic variables are not individual-level variables, caution is required in their interpretation. The stability across the models of the odds ratios for the primary exposure variable for two cancers in females, bladder cancer and leukemia, suggests that the estimated significantly elevated risk for these two cancers is not due to confounding. In the following section, more detailed results of the logistic regression analyses are presented for each cancer site separately.

The ecological nature of the control variables contributes to the difficulty of interpreting unexpected protective effects. While it is certainly possible that some environmental contaminants inhibit the development of cancer, it is also important to qualify the interpretation of the control variables which are based on available geographical data. It is possible that the control variables serve as more accurate indicators of a geographic area's economic environment than its physical environment. For example, many of the hazardous waste sites in these areas are former industrial sites. Areas with more hazardous waste sites may represent economically depressed areas, in contrast to areas with TRI sites, which are more economically healthy. It is possible that both the TRI variable and the hazardous waste site variables are serving as indicators of social and economic differences among study subjects, rather than controlling for environmental factors, as intended.

Some of the estimated effects of the environmental and demographic variables raise questions however about their validity as indicators for the intended social, economic and environmental factors. The important role of low income as a predictor of lowered cancer risk in these data is shown in that ten out of the fourteen cancer analyses show this variable as statistically significantly associated with lowered risk of cancer in the final model. The strength of income effects, which are very simply modeled as a dichotomous variable for low income, points to the possibility that the other variables, including the environmental variables which are based on geographic location, may also be acting in the models as indicators of socio-economic factors which may be related to risk for cancer. Because this study used non-cancer deaths as controls, risk factors for early death related to socio-economic status are likely playing a role in this study's findings as well.

Residence near a hazardous waste site (other than the off-gassing landfills), for example, for which the crude odds ratios show lowered but not statistically significant reduced risk for any of the cancer sites, becomes statistically significantly low in model 2 which includes environmental, but not demographic variables, for eight of the fourteen cancer analyses. When the demographic variables and interactions are added in model 4, the hazardous waste site variable is statistically significantly low for five cancer analyses, lung in females and males, bladder in females, non-Hodgkin's lymphoma in females, and kidney cancer in males. For no cancer does this variable show an elevated odds ratio in any of the analyses. This suggests that the hazardous waste site variable may be playing a role as an economic indicator rather than environmental indicator.

In summary, the logistic modeling process did not result in any change in the statistical significance of the study's results. Odds ratios for bladder cancer in females and leukemia in females for potential exposure to landfills with soil migration conditions remained statistically significantly elevated and increased in value. The parameter estimates for the various environmental and demographic variables included in the multiple logistic regression models showed unexpected protective effects for environmental variables. The strength of the associations shown for the income variable in the models indicates that socio-economic factors are playing a substantial role in these data.

Table B-1
Logistic Regression Models for Cancers in Females

Liver	Model 1 (p=.295)			Model 2 (p=.426)			Model 3 (p=.136)			Model 4 (p=.060)0		
	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value
Off-gassing landfill buffer	4.73	0.29-76.5	.273	8.33	0.41-168	.167	10.3	0.40-269	.161	7.90	0.41-152	.171
<=500 ft from buffer				1.34	0.14-12.7	.800	1.51	0.15-14.8	.726			
<=1/2 mile of TRI facility				1.44	0.45-4.57	.534	1.63	0.50-5.33	.416			
<=1500 ft from other hws				0.31	0.06-1.56	.156	0.36	0.07-1.76	.206			
low income							0.72	0.38-1.36	.303			
low duration of residence							0.63	0.22-1.75	.373			
high population density							0.40	0.11-1.41	.154	0.31	0.09-1.08	.066

Lung	Model 1 (p=.471)			Model 2 (p=.0001)			Model 3 (p=.0001)			Model 4 (p=.0001)		
	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value
Off-gassing landfill buffer	1.35	0.60-3.05	.466	2.00	0.86-4.67	.109	1.85	0.79-4.31	.155	1.71	0.73-4.02	.217
<=500 ft from buffer				1.17	0.71-1.93	.537	1.31	0.79-2.18	.299			
<=1/2 mile of TRI facility				0.70	0.50-0.96	.028**	0.75	0.54-1.05	.091			
<=1500 ft from other hws				0.52	0.37-0.71	.0001**	0.53	0.38-0.73	.0001**	0.24	0.11-0.53	.0003**
low income							0.65	0.55-0.77	.0001**	0.66	0.56-0.78	.0001**
low duration of residence							0.98	0.78-1.23	.859			
high population density							1.18	0.95-1.45	.129			
tri * population										0.95	0.90-0.99	.036**
hws * population										1.16	1.03-1.31	.017**

Bladder	Model 1 (p=.017)			Model 2 (p=.0007)			Model 3 (p=.0001)			Model 4 (p=.0001)		
	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value
Off-gassing landfill buffer	4.08	1.36-12.2	.012**	6.01	1.87-19.3	.003**	5.56	1.69-18.3	.005**	5.52	1.67-18.2	.005**
<=500 ft from buffer				1.40	0.59-3.33	.450	1.99	0.81-4.89	.133	2.00	0.81-4.91	.132
<=1/2 mile of TRI facility				0.42	0.19-0.93	.032**	0.44	0.20-0.97	.042**	7.94	1.22-51.7	.030**
<=1500 ft from other hws				0.49	0.26-0.91	.023**	0.47	0.25-0.87	.017**	0.47	0.25-0.88	.018**
low income							0.66	0.49-0.89	.006**	0.64	0.48-0.87	.004**
low duration of residence							0.48	0.30-0.77	.002**	0.48	0.30-0.77	.003**
high population density							2.27	1.65-3.12	.0001**	2.37	1.72-3.27	.0001**
TRI * population										0.65	0.47-0.91	.010**
TRI * inc										0.72	0.45-1.18	.193

Table B-1 (continued)

Kidney	Model 1 (p=.350)			Model 2 (p=.170)			Model 3 (p=.018)			Model 4 (p=.001)		
	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value
Off-gassing landfill buffer	2.36	0.43-12.9	.322	2.59	0.46-14.5	.280	2.56	0.45-14.5	.289	2.25	0.41-12.4	.351
<=500 ft from buffer				1.04	0.34-3.20	.939	1.23	0.40-3.83	.716			
<=1/2 mile of TRI facility				0.47	0.22-1.05	.065	0.53	0.24-1.17	.116	0.51	0.23-1.13	.098
<=1500 ft from other hws				0.77	0.42-1.41	.395	0.77	0.42-1.42	.401			
low income							0.62	0.44-0.87	.006**	0.60	0.44-0.83	.002**
low duration of residence							0.87	0.55-1.38	.547			
high population density							1.08	0.71-1.67	.713			

Brain	Model 1 (p=.349)			Model 2 (p=.210)			Model 3 (p=.087)			Model 4 (p=.032)		
	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value
Off-gassing landfill buffer	2.37	0.43-13.0	.321	3.41	0.58-19.9	.174	3.54	0.60-20.8	.162	3.29	0.57-19.1	.185
<=500 ft from buffer				1.53	0.31-7.51	.598	1.77	0.35-8.85	.488			
<=1/2 mile of TRI facility				1.05	0.50-2.19	.908	1.12	0.53-2.38	.760			
<=1500 ft from other hws				0.43	0.19-0.98	.046**	0.43	0.19-0.98	.044**	0.45	0.20-1.02	.056
low income							0.73	0.50-1.06	.099	0.68	0.48-0.97	.036**
low duration of residence							0.70	0.40-1.21	.199			
high population density							1.09	0.65-1.82	.747			

Non-Hodgkin's Lymphoma	Model 1 (p=.606)			Model 2 (p=.027)			Model 3 (p=.0001)			Model 4 (p=.0001)		
	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value
Off-gassing landfill buffer	1.42	0.39-5.18	.595	2.23	0.58-8.65	.246	2.11	0.54-8.21	.280	2.03	0.52-7.85	.306
<=500 ft from buffer				1.29	0.55-3.04	.565	1.55	0.65-3.71	.324			
<=1/2 mile of TRI facility				0.70	0.40-1.25	.228	0.78	0.44-1.39	.397	7.62	1.85-31.5	.005**
<=1500 ft from other hws				0.47	0.26-0.85	.012**	0.48	0.27-0.86	.014**	0.50	0.28-0.89	.018**
low income							0.64	0.49-0.85	.002**	0.61	0.46-0.81	.001**
low duration of residence							0.69	0.46-1.03	.072	0.71	0.48-1.07	.099
high population density							0.96	0.66-1.39	.816			
TRI * income										0.71	0.50-1.00	.053
TRI * population										0.74	0.58-0.93	.011**

Table B-1 (continued)

Leukemia	Model 1 (p=.019)			Model 2 (p=.077)			Model 3 (p=.038)			Model 4 (p=.009)		
	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value
Off-gassing landfill buffer	4.76	1.37-16.5	.014**	5.45	1.54-19.3	.009**	5.31	1.50-18.8	.010**	5.13	1.45-18.1	.011**
<=500 ft from buffer				1.24	0.45-3.39	.678	1.43	0.52-3.97	.492			
<=1/2 mile of TRI facility				1.26	0.72-2.23	.422	1.31	0.74-2.32	.362			
<=1500 ft from other hws				0.62	0.33-1.14	.120	0.63	0.34-1.16	.140	0.68	0.38-1.22	.198
low income							0.81	0.59-1.10	.173	0.81	0.60-1.11	.187
low duration of residence							0.71	0.45-1.14	.156	0.71	0.45-1.12	.138
high population density							0.93	0.61-1.43	.745			

Variable definitions:

	Values	Definition
Off-gassing landfill buffer	0,1	1=Residence within off-gassing landfill buffer (usually 250 feet) at diagnosis (cases) or death (controls)
<=500 ft from buffer	0,1	1=Residence within the 500 feet adjacent to the landfill buffer
<=1/2 mile of TRI facility	0,1	1=Residence within ½ mile of a manufacturing facility reporting TRI releases from 1988-1993
<= 1500 ft from other hws	0,1	1=Residence within 1500 feet of listed inactive hazardous waste sites (other than the off-gassing landfills)
low income	0,1	1=Residence in a block group ranking among the lowest 20% for study subject's block group average household income.
low duration of residence	0,1	1=Residence in a block group in the highest decile for percentage of households with less than ten years at current address.
high population density	0,1	1=Residence in a block group in the highest decile of study subjects' block group population density.
hws*income	0-9	1-9=Residence within 1500 feet of a hazardous waste site, from 1-9=low to high block group income decile
hws*population	0-9	1-9=Residence within 1500 feet of a hazardous waste site, from 1-9=low to high population density decile
TRI*income	0-9	1-9=Residence within ½ mile of a TRI facility, from 1-9=low to high income decile
TRI*population	0-9	1-9=Residence within ½ mile of a TRI facility, from 1-9=low to high population density decile

Table B-2
Logistic Regression Models for Cancers in Males

Lung	Model 1 (p=.372)			Model 2 (p=.143)			Model 3 (p=.150)			Model 4 (p=.024)		
	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value
Off-gassing landfill buffer	1.41	0.67-2.99	.367	1.55	0.73-3.30	.257	1.56	0.73-3.32	.250	1.57	0.74-3.34	.242
<=500 ft from buffer				0.88	0.58-1.34	.545	0.87	0.57-1.32	.503			
<=1/2 mile of TRI facility				1.05	0.84-1.30	.677	1.05	0.84-1.30	.684			
<=1500 ft from other hws				0.78	0.63-0.98	.030**	0.78	0.63-0.98	.029**	0.77	0.62-0.96	.017**
low income block group							0.97	0.86-1.09	.570			
short duration of residence							1.08	0.90-1.28	.413			
high population density							1.14	0.98-1/33	.101	1.15	0.99-1.34	.075

Bladder	Model 1 (p=.775)			Model 2 (p=.392)			Model 3 (p=.0001)			Model 4 (p=.0001)		
	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value
Off-gassing landfill buffer	1.18	0.39-3.53	.771	1.32	0.43-4.00	.627	1.25	0.41-3.80	.695	1.30	0.42-3.97	.651
<=500 ft from buffer				1.13	0.64-1.99	.670	1.23	0.70-2.18	.471			
<=1/2 mile of TRI facility				0.84	0.60-1.18	.314	0.90	0.64-1.26	.530			
<=1500 ft from other hws				0.78	0.56-1.09	.147	0.81	0.58-1.13	.206			
low income							0.70	0.58-0.84	.0002**	0.69	0.57-0.83	.0001**
low duration of residence							0.71	0.53-0.95	.020**	0.71	0.53-0.95	.020**
high population density							1.18	0.94-1.47	.157	1.20	0.96-1.51	.107
hws*inc										0.95	0.88-1.02	.170
tri*pop										0.96	0.91-1.02	.187

Leukemia	Model 1 (p=.314)			Model 2 (p=.355)			Model 3 (p=.017)			Model 4 (p=.003)		
	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value
Off-gassing landfill buffer	1.87	0.59-6.00	.291	2.30	0.70-7.58	.173	2.20	0.66-7.28	.199	2.16	0.65-7.14	.207
<=500 ft from buffer				1.34	0.57-3.18	.507	1.43	0.60-3.42	.418			
<=1/2 mile of TRI facility				0.92	0.54-1.57	.753	1.00	0.59-1.72	.992			
<=1500 ft from other hws				0.63	0.36-1.09	.097	0.66	0.38-1.15	.142	0.69	0.40-1186	.174
low income							0.70	0.52-0.94	.019**	0.70	0.52-0.93	.015**
low duration of residence							0.67	0.42-1.06	.085	0.66	0.42-1.04	.074
high population density							0.92	0.62-1.36	.682			

Table B-2 (continued)

Variable definitions for Table B-2:

	Values	Definition
Off-gassing landfill buffer	0,1	1=Residence within off-gassing landfill buffer (usually 250 feet) at diagnosis (cases) or death (controls)
<=500 ft from buffer	0,1	1=Residence within the 500 feet adjacent to the landfill buffer
<=1/2 mile of TRI facility	0,1	1=Residence within ½ mile of a manufacturing facility reporting TRI releases from 1988-1993
<= 1500 ft from other hws	0,1	1=Residence within 1500 feet of listed inactive hazardous waste sites (other than the off-gassing landfills)
low income	0,1	1=Residence in a block group ranking among the lowest 20% for study subject's block group average household income.
low duration of residence	0,1	1=Residence in a block group in the highest decile for percentage of households with less than ten years at current address.
high population density	0,1	1=Residence in a block group in the highest decile of study subjects' block group population density.
hws*income	0-9	1-9=Residence within 1500 feet of a hazardous waste site, from 1-9=low to high block group income decile
hws*population	0-9	1-9=Residence within 1500 feet of a hazardous waste site, from 1-9=low to high population density decile
TRI*income	0-9	1-9=Residence within ½ mile of a TRI facility, from 1-9=low to high income decile
TRI*population	0-9	1-9=Residence within ½ mile of a TRI facility, from 1-9=low to high population density decile

Table B-3
Logistic Regression Models for Cancers (with no exposed cases) in Males

Liver	Model 1 (p=.355)			Model 2 (p=.270)			Model 3 (p=.450)			Model 4 (p=.039)		
	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value
Off-gassing landfill buffer and <=500 ft from buffer	0.42	0.05-3.30	.411	0.55	0.07-4.54	.581	0.55	0.07-4.55	.578	0.41	0.05-3.22	.399
<=1/2 mile of TRI facility				0.60	0.21-1.74	.350	0.63	0.21-1.82	.388			
<=1500 ft from other hws				0.48	0.14-1.64	.241	0.50	0.15-1.72	.272			
low income block group							0.75	0.46-1.23	.250			
short duration of residence							1.20	0.59-2.44	.622			
high population density							1.20	0.64-2.27	.571			
tri*pop										0.66	0.44-0.99	.944
tri*inc										1.36	0.99-1.86	.060

Kidney	Model 1 (p=.476)			Model 2 (p=.026)			Model 3 (p=.005)			Model 4 (p=.0001)		
	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value
Off-gassing landfill buffer and <=500 ft from buffer	0.74	0.31-1.75	.491	1.04	0.42-2.56	.933	1.10	0.45-2.72	.832	1.05	0.42-2.60	.915
<=1/2 mile of TRI facility				1.18	0.74-1.98	.482	1.19	0.74-1.92	.472			
<=1500 ft from other hws				0.40	0.20-0.79	.008**	0.40	0.20-0.79	.008**	0.19	0.05-0.73	.016**
low income block group							0.76	0.57-1.00	.054	0.81	0.61-1.07	.132
short duration of residence							0.86	0.56-.30	.463			
high population density							1.51	1.08-2.10	.015**	1.54	1.11-2.13	.010**
hws*inc										1.21	0.96-1.52	.110
tri*pop										0.88	0.77-0.99	.034**
tri*inc										1.26	1.09-1.46	.001**

Brain	Model 1 (p=.0350)			Model 2 (p=.039)			Model 3 (p=.0001)			Model 4 (p=.0001)		
	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value
Off-gassing landfill buffer and <=500 ft from buffer	0.19	0.03-1.42	.106	0.24	0.03-1.79	.162	0.23	0.03-1.74	.155	0.21	0.03-1.58	.132
<=1/2 mile of TRI facility				0.73	0.36-1.50	.397	0.88	0.42-1.83	.738			
<=1500 ft from other hws				0.51	0.22-1.22	.131	0.52	0.22-1.25	.144			
low income block group							0.53	0.35-0.80	.002**	0.54	0.36-0.80	.002**
short duration of residence							0.38	0.19-0.77	.007**	0.39	0.19-0.79	.008**
high population density							1.18	0.74-1.89	.483			
hws*pop										0.85	0.70-1.02	.074

Table B-3 (Continued)

Non-Hodgkin's Lymphoma	Model 1 (p=.912)			Model 2 (p=.778)			Model 3 (p=.008)			Model 4 (P=.001)		
	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value
Off-gassing landfill buffer and <=500 ft from buffer	0.96	0.47-1.98	.912	1.06	0.50-2.24	.882	1.12	0.53-2.37	.773	0.98	0.48-2.03	.965
<=1/2 mile of TRI facility				1.16	0.75-1.79	.508	1.28	0.82-1.99	.275			
<=1500 ft from other hws				0.81	0.51-1.28	.370	0.83	0.53-1.31	.430			
low income block group							0.62	0.47-0.82	.001**	0.62	0.48-0.81	.0005**
short duration of residence							0.79	0.53-1.17	.236			
high population density							1.23	0.90-1.69	.198			

Variable definitions for Table B-3:

	Values	Definition
Off-gassing landfill buffer	0,1	1=Residence within off-gassing landfill buffer (usually 250 feet) at diagnosis (cases) or death (controls)
<=500 ft from buffer	0,1	1=Residence within the 500 feet adjacent to the landfill buffer
<=1/2 mile of TRI facility	0,1	1=Residence within ½ mile of a manufacturing facility reporting TRI releases from 1988-1993
<= 1500 ft from other hws	0,1	1=Residence within 1500 feet of listed inactive hazardous waste sites (other than the off-gassing landfills)
low income	0,1	1=Residence in a block group ranking among the lowest 20% for study subject's block group average household income.
low duration of residence	0,1	1=Residence in a block group in the highest decile for percentage of households with less than ten years at current address.
high population density	0,1	1=Residence in a block group in the highest decile of study subjects' block group population density.
hws*income	0-9	1-9=Residence within 1500 feet of a hazardous waste site, from 1-9=low to high block group income decile
hws*population	0-9	1-9=Residence within 1500 feet of a hazardous waste site, from 1-9=low to high population density decile
TRI*income	0-9	1-9=Residence within ½ mile of a TRI facility, from 1-9=low to high income decile
TRI*population	0-9	1-9=Residence within ½ mile of a TRI facility, from 1-9=low to high population density decile

FACT SHEET

INVESTIGATION OF CANCER INCIDENCE NEAR 38 LANDFILLS WITH SOIL GAS MIGRATION CONDITIONS: NEW YORK STATE, 1980-1989

July 1998

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SUMMARY

The New York State Department of Health (DOH) conducted this study to find out if people living near certain landfills had an increased risk of cancer compared to people living elsewhere. The landfills studied were older municipal landfills. Municipal landfills contain household garbage which breaks down, creating methane gas. Previous investigations showed that methane can move away from landfills and carry other chemicals present in the landfill with it.

When this mixture of gases moves away from a landfill through air pockets in soil, people can be exposed in their homes. Previous DOH studies suggested possible health effects near a landfill where chemical exposures had occurred in indoor air. After review of these studies, DOH and the federal Agency for Toxic Substances and Disease Registry (ATSDR) recommended that DOH conduct a larger health study to evaluate possible cancer effects among people living near a group of landfills of this type.

From 245 landfills identified in the state, 38 were selected for the study. The information available for each of the selected landfills showed directly or provided strong evidence that the landfill contents were creating methane gas. Twenty-six landfills had soil gas sampling data. Nine of these had data only on methane levels in soil gas, two had data on other chemicals in soil gas, and fifteen had data for both methane and other chemicals in soil gas. For the 12 other landfills where soil gas was not sampled for methane or specific chemicals, methane or other chemicals were found in ambient air or water within the landfill boundary. By evaluating these data along with information about what was buried in the landfill and what type of soils surrounded it, the researchers concluded that these 12 landfills should be included in the study.

For each of the 38 landfills an area, or ring, around the landfill boundary was identified where people may have been exposed to landfill chemicals through soil gas moving into homes. For twelve of the 38 landfills, soil gas samples had been taken outside the landfill boundaries. From this sampling information, the researchers estimated the migration distances for the other landfills where this type of sampling had not been done. The potential exposure areas, or rings, extended 250 feet from the landfill boundaries for 33 landfills. The other five landfills were given larger rings based on sampling results showing methane in soil at specific distances from the landfills. (For four of these landfills, the ring extended out 500 feet, and for one landfill it extended 1,000 feet.)

The study evaluated cancer incidence among people living in the zip codes containing these 38 landfills. All cases of leukemia, non-Hodgkin's lymphoma, liver, lung, kidney, bladder and brain cancer diagnosed from 1980 to 1989 in these zip codes were located on a map. A random sample of people who did not have these seven cancers were selected as controls. The controls came from the same zip codes and their addresses were located on a map as well. The researchers then looked to see if people with cancer were more likely than people without cancer to live in the rings surrounding the landfills.

The data available for this study were limited. There were no data that measured whether individuals were exposed to landfill chemicals. Only a person's address at the time of diagnosis was used for mapping his or her location. The length of time people lived at their

homes before being diagnosed with cancer was unknown; a person in the study could have just recently moved to the address. This is important because there is a period of years, called latency, between the beginning of the cancer's growth and its later appearance and diagnosis.

For most cancers, the period of latency is thought to be between ten and twenty years. For cancer studies, researchers would like to know where people lived and what they were exposed to at least twenty years before cancer is diagnosed. But this is rarely possible. This study looked back from cancers diagnosed in the 1980's to potential exposures that might have occurred near landfills that were active in the 1960's and 1970's. This type of study cannot prove a direct cause and effect relationship between exposure and disease.

Since the 1960's and 1970's, when individuals in this study may have been exposed to landfill gases, clean-up activities and landfill closings have changed the conditions at New York State's landfills. This study does not provide us with information about health risks related to living near landfills today.

Study Findings:

- Of the people in the study zip codes diagnosed with any of the seven types of cancer (9,020) over the ten-year period 1980-1989, fewer than one percent (49) lived in the landfill potential exposure areas (rings) at diagnosis. Fewer than one percent of the people without cancer (controls) lived in the rings around the landfill as well.
- Among the study's 397 women with bladder cancer, six cases (1.51%) lived in the rings when they were diagnosed. Seven of the study's 1,869 controls (0.37%) lived in the rings. This difference in percentages produced an estimate of a four-fold elevation of risk for bladder cancer among women living in the exposure areas.
- Among the study's 335 females with leukemia, five cases (1.49%) and five of the 1,575 controls (0.32%) lived in the rings around the landfills. This difference produced an estimate that the risk of leukemia for women living inside the rings was about four times higher than for women living outside them.
- For men living in the rings around the landfills, the risk for leukemia and risk for bladder cancer were not shown to be higher than for men living outside the rings.
- Risks for the other five types of cancer, non-Hodgkin's lymphoma, liver, lung, kidney and brain, for women and men living in the rings were not shown to be higher than for those living outside the rings.

These findings need to be interpreted carefully in light of the many problems researchers face when studying cancer incidence in communities. First, one such study alone cannot prove a relationship between an exposure and a disease. Several such studies with similar results are usually needed for scientists to agree that there is evidence for an exposure-disease relationship. In addition, the findings of this particular study cannot be used to draw strong conclusions about cancer risks around these specific landfills because of the data limitations discussed above. These findings do, however, require follow-up.

DOH is currently conducting a review of the medical records for the leukemia and bladder cancer cases who lived in the potential exposure areas near the study's landfills. A follow-up study is planned using a different group of study controls to see if this study's findings can be verified. The study will also be updated, using cancers diagnosed through 1994. To better assess the study hypothesis that hazardous chemicals moved from these landfills through soil gas into residential areas, the follow-up study will include additional review of data that is relevant to past landfill conditions. In addition, sampling will be conducted at selected landfills to assess current conditions.

None of this study's landfills remain open today. All of the study's landfills have been investigated by DOH and New York State Department of Environmental Conservation (DEC). These investigations addressed the potential for human exposures and health problems related to each landfill site. The actions taken to improve conditions at closed landfills depend on specific characteristics at each site. Remedial actions have included installing systems for collecting landfill gas, capping the landfill, collection of leachate (water run-off) from the landfill, intercepting and treating contaminated groundwater plumes, and continued groundwater monitoring and air monitoring of landfill vents.

QUESTIONS AND ANSWERS

1. Why was this study done? Problems with methane and hazardous volatile organic chemicals (VOCs) have been documented at various landfills in New York State. After several small explosions near furnaces in homes close to Port Washington Landfill, air was sampled in a few homes in 1981. Levels of vinyl chloride, benzene, 1,1,1-trichloroethane, and 1,1,2-trichloroethane in these samples were higher than usual (background) levels. Indoor air samples were taken near two other study landfills, and they did not show VOC levels above expected levels.

The situation at Port Washington Landfill led to the joint DOH and ATSDR recommendation that DOH conduct further health studies. Methane migration conditions were known to exist at other landfills. It did not make sense to study landfills one-by-one because the number of people living near any one landfill is too small for a cancer study. So this study combined information about cancers diagnosed in the 1980's in the areas surrounding the 38 landfills in the state that were judged to have had similar soil gas (methane) migration and hazardous VOC conditions in the 1960's and 1970's.

2. How were the landfills selected for the study? The researchers started with 245 municipal landfills that were included or had been considered for inclusion on the New York State Registry of Inactive Hazardous Waste Sites. After examining population data for these sites, 125 were eliminated because they were located in rural areas with too few people nearby (fewer than 300 people living within ½ mile of the landfill boundary). From the 120 sites remaining, 38 landfills were selected based on data showing methane gas or other chemicals in soil gas or other samples as described on page 1. This fact sheet includes a table showing the 38 landfills listed according to the zip codes that contain them. The table shows each landfill's size, the years it was active, and whether it has a methane collection system.

3. How was the study done? In this type of study, called a case-control study, two groups are selected. The first is a group of people referred to as cases who were diagnosed with any of the seven types of cancer, leukemia, non-Hodgkin's lymphoma, liver, lung, kidney, bladder and brain cancer, from 1980 to 1989. The second is a group of people referred to as controls who were selected from the same population as the cases, but who have not had cancer. For this study, five controls were selected for each case.

The New York State Cancer Registry was used to find every person who lived in the study's zip codes and was diagnosed between 1980 and 1989 with any of the seven cancers as a primary cancer. Leukemia, non-Hodgkin's lymphoma, liver, lung, kidney, bladder and brain cancer were chosen for the study because they have been linked to occupational chemical exposures in scientific studies. The control group was chosen from data from death certificate files maintained by DOH. The controls were a random sample of all non-cancer deaths occurring in the same zip codes as the cases. The DOH files provided needed information about address and date of birth, so that the control group was comparable in age to the cancer case group.

The study researchers looked to see if there was a clear difference between the people with cancer (cases) and without cancer (controls). If such a difference is found, it helps point the researchers toward a possible cause. In this case, the researchers looked to see if the people with cancer were more likely to live in the rings around the landfills than the people without cancer. All the study cases and controls lived in the zip codes containing the landfills. Once each person's exact address was mapped, the researchers could see who lived in the landfill rings, and could estimate whether the percentage of the cases living near the landfills was higher than expected, using the locations of the controls for comparison.

4. What chemicals were considered in the study? The VOCs detected most often at the 19 landfills where VOCs were sampled in soil gas were tetrachloroethene (PCE or perc), trichloroethene (TCE), toluene, 1,1,1-trichloroethane (TCA), benzene, vinyl chloride, xylene, ethylbenzene, methylene chloride, 1,2-dichloroethene and chloroform. These frequently detected chemicals should be considered as general indicators of chemical contamination because the soil gas likely contained other chemicals in addition to those for which it was monitored. This means that even if a cause and effect relationship is suspected, the specific causative agent cannot be identified.

5. How can people be exposed to landfill chemicals? The methane gas which is produced in landfills during the breakdown of household wastes travels through air pockets in soil. The methane carries other chemicals along with it. Buildings create regions of lower air pressure which can draw air and soil gases from the surrounding soil through cracks or other openings in the basement or slab. In this way, people residing near landfills could possibly be exposed to hazardous components of landfill gas.

6. Were the cancer risks analyzed separately for each of the 38 landfills? No, the landfills could not be looked at separately because the number of people living near any one particular landfill was too small to do statistical analysis. For each type of cancer, the study cases and controls from all the zip codes containing the 38 landfill potential exposure areas were combined into one group for the analyses.

7. Were the study subjects contacted and interviewed? The cases and controls in this study were not contacted directly. So the researchers did not have information about each person's smoking habits, occupational exposures, medical history, or other cancer risk factors. A case-control study is designed so that the people in the study all come from the same population. There is no reason to think that the people living in the landfill potential exposure areas would have different smoking habits or occupations from their neighbors living just a little further away from the landfill. The lack of individual information, however, is a limitation of this study. It is possible that personal risk factors that were not identified could have played a role in the findings.

8. Were the study's findings statistically significant? The findings for a four-fold elevation of risk for bladder cancer and leukemia for women living in the rings around the landfills are statistically significant. This means that the statistical tests show that it is very unlikely, but not impossible, that the higher than expected number of cases of these two types of cancer in the landfill rings occurred just by chance. For the seven cancers examined in males and the other five cancers examined in females, there were no statistically significant findings. The statistically significant findings of the study still need to be judged based on the study's methods. The findings need to be interpreted with caution because this study did not have the type of data available that could point directly to a cause and effect relationship.

9. What does this study tell us about cancer incidence and landfills? The study used data from existing records to provide scientists with leads about possible connections between environmental exposures and disease. The study succeeded in combining information about 38 landfills in New York State to look at several different types of cancer among people living very close to specific landfills. The study's data limitations prevent us from drawing strong conclusions from this one study, however.

An important finding of this study is that there were relatively few people, less than one percent of the study population, living in the landfill potential exposure areas. Less than one percent of the cancers identified in this study occurred among people living in the potential exposure areas. Because very few people live close enough to the landfills for exposures to possibly occur, very few cancers can potentially be attributed to this possible risk factor.

10. I have lived for many years near a landfill included in the study. Should I be concerned? This study did not prove that there is a relationship between living very close to the study landfills and female bladder cancer or leukemia. But the study findings do suggest that there may be an increased risk for these cancers for women who lived within 250 feet of the landfills during the 1960's and 1970's. For a woman faced with this possibility it is important to remember that bladder cancer and leukemia are rare cancers in women. While any increased risk would be a concern, these rare cancers are still less likely to occur than many other more common health problems.

Over an entire lifetime (living 95 or more years), a woman's risk of being diagnosed with bladder cancer is about 1 out of 100, and her risk for leukemia is also about 1 out of 100. This study's estimate of a possible four-fold increase in risk for bladder cancer and leukemia would increase the estimated lifetime risk of being diagnosed with bladder cancer to about 4 out of 100 and the estimated lifetime risk of being diagnosed with leukemia to about 4 out of 100. Over a 95-year-lifetime, a woman's risk of being diagnosed with lung cancer is 5 out of 100 and her risk of being diagnosed with breast cancer is about 12 out of 100.

For cancers which are often curable, such as bladder cancer and leukemia (and breast cancer), the chances of dying from these cancers are smaller than the chances of being diagnosed with them. People often do not realize that heart disease is the biggest health risk women face. About nine times more women die each year from heart disease than from breast cancer. If you are concerned about a possible increased cancer risk, you should discuss it with your physician. Your physician may also call the Environmental Health Informationline at 1-800-458-1158, ext. 6402 to discuss this further with DOH staff.

11. I live near a landfill that was not included in the study. Should I be concerned? Specific conditions must exist for landfill gases to move through the soil and reach residential areas. Of the 245 landfills examined by this study's researchers, only 38 met the study conditions for possible exposures through soil gas migration to residents living nearby. The other 207 landfills did not meet these conditions. This study did not evaluate current conditions at landfills. The cancers investigated in the study occurred in the 1980's. Sites were identified which might have caused exposures in the 1960's and 1970's.

12. What has been done to correct problems at the landfills included in this study? Most of the study landfills (30) began operating before 1970. Many of these older landfills were not lined and capped as they would be if constructed today. By the end of the 1980's only three of the landfills were still operating, and none of the landfills remain open today. Methane collection systems for decreasing methane migration away from the landfills began to be used in the late 1970's. Twenty-two of the study's landfills currently have methane collection systems in place and four more are planned to be constructed in 1998. The landfills in this study have been evaluated as hazardous waste sites by DOH and DEC. A variety of corrective actions, usually including capping the landfill and maintaining methane collection systems, have been taken at the sites.

13. What is the current status of landfills in general in New York State? After New York State (1973) and the federal government (1976) began regulating landfills, existing open dumps were either closed or upgraded to sanitary landfills, which have a clean fill cover placed on top of the solid waste. In 1988 the New York State legislature passed the Solid Waste Management Act which set priorities for solid waste management in New York State. It required New York State communities to develop programs following this ordering of priorities: (1) reducing the generation of waste, (2) reusing and recycling, (3) recovering energy from waste that cannot be recycled, and (4) disposing by land burial or other means approved by DEC.

In 1988, DEC also revised its regulations, known as "Part 360," for constructing, operating and closing non-hazardous landfills. The Part 360 regulations also include rules for monitoring non-hazardous landfill conditions after closure. Since 1988, the number of active landfills accepting municipal solid waste in New York State has decreased from about 240 to 39. The active landfills remaining tend to be large because the rules for building and running landfills are more strict and this makes the larger ones more economical. Many of the remaining landfills are privately owned; others are owned by cities or counties. They are regulated by DEC, Division of Solid and Hazardous Materials. Of the 39 active municipal solid waste landfills, 38 of them are either lined, have perimeter gas migration cutoff trenches, or are located in soils with low permeability. The 39th landfill is a small rural landfill in Hamilton county. This landfill is scheduled to close in 1999 with State assistance provided by th 1996 CleanWater/Clean Air Bond Act in accordance with Part 360, which addresses landfill gas migration.

FOR MORE INFORMATION about this study please contact:

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Investigation of Cancer Incidence and Residence Near
38 Landfills with Soil Gas Migration Conditions:
New York State, 1980-1989
38 Landfills Selected for Inclusion in the Study

Zip Codes	County	Site Number	Site Name	Buffer Width	LF Acres	Methane* Collection	Active Years
10543	Westchester	360021	Mamaroneck Srs.	250	8	P-1996	50-70
10950	Orange	336027	Mayer LF	250	20	None	49-75
10994	Rockland	344006	Nyack LF	250	12	P-TBC1998	51-83
10994,10960	Rockland	344001	Clarkstown Town LF	500	80	A-TBC1998	40-90
11040	Nassau	130008	Denton Ave LF	250	54	P-1975	53-74
11050	Nassau	130025	Port Washington LF	1000	53	A&P-1982	74-83
11542	Nassau	130032	Garvies Point	250	19	None	71-80
11572	Nassau	130023	Oceanside LF	250	181	P-1983	62-88
11722,11788	Suffolk	152084	Watch Hill Sand & Gravel#	250	45	P-1988	60s-80
11722,11788	Suffolk	152002	Blydenburgh LF	500	55	A-1983	27-90
11725	Suffolk	152043	Smithtown LF	250	20	A-1983	10-79
11725	Suffolk	152044	Smithtown Sanitary LF	250	24	A-1984	78-84
11725	Suffolk	152096	Steck & Philbin#	250	5	None	70s-80s
11725,11731	Suffolk	152040	Huntington LF	250	44	A-1982	35-89
11741	Suffolk	152053	Sayville LF	250	30	P-1984	38-85
11742	Suffolk	152010	Holtsville LF	250	74	A-1979	68-74
11754,11787	Suffolk	152097	Star Sand & Gravel	250	3	None	78-85
11767,11780	Suffolk	152042	South Montclair Ave LF	250	20	A-1978	67-70
11791	Nassau	130011	Syosset LF	250	35	P-1981	36-75
11804	Nassau	130001	Old Bethpage LF	500	65	A-1982	58-86
11937	Suffolk	152058	East Hampton LF	250	45	A-TBC1998	60-93
11968	Suffolk	152052	North Sea LF	250	13	P-1988	63-95
12078	Fulton	518001	Gloversville LF	250	80	P-1997	57-89
12144	Rensselaer	442003	Former Rensselaer City LF	250	12	None	57-76
12508	Dutchess	314024	Beacon City LF(inactive)	250	5	None	30-68
12508	Dutchess	314046	Beacon City LF	250	17	P-1993	68-83
12603	Dutchess	314047	Dutchess Sanitation	250	19	A-1994	71-85
13205	Onondaga	734037	Brighton Ave LF	250	35	None	43-78
13215	Onondaga	734009	Tripoli LF	250	75	P-1984	39-85
13492	Oneida	633013	Whitestown Municipal LF	500	30	P-1992	67-91
13748	Broome	704013	Conklin Dump	250	37	P-1994	64-75
14048	Chautauqua	907003	Dunkirk LF	250	27	P-1979	66-78
14101	Cattaraugus	905021	Machias LF	250	7	None	70-80
14120	Niagara	932026	Niagara County Refuse	250	50	P-TBC1998	69-76
14467	Monroe	828037	Henrietta Town Dump	250	19	None	50-65
14534	Monroe	828048	Pittsford Town Dump	250	13	None	33-82
14617	Monroe	828009	Old Rochester/Pattonwood	250	28	None	56-62
14845	Chemung	808011	Horseheads LF	250	25	None	40-73

*This column indicates whether the site has an active (A=Active) or passive (P=Passive) methane collection system and the year the system was installed. TBC indicates that a system is planned to be constructed.
#For these landfills, dates of operation are estimated from available information.