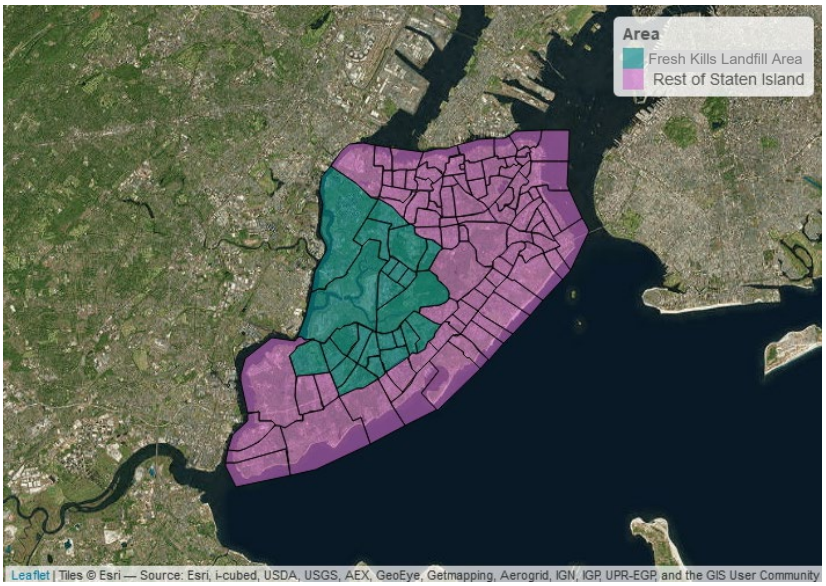
A Descriptive Study of Cancer and Other Health Outcomes Around the Former Fresh Kills Landfill, Staten Island

January 2020

Aerial view of Staten Island. Photo by Alex MacLean. Image courtesy of Freshkills Park and the City of New York.



A satellite image of Staten Island overlaid with 2010 United States Census tract definitions.

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Executive Summary

Introduction

The former Fresh Kills Landfill site – once one of the world's largest landfills – is being transformed into one of New York City's largest parks. The landfill began operation in 1948. Both while the landfill was operating and since its closure in 2001, residents of Staten Island have had concerns about potential environmental exposures resulting in adverse health impacts, such as cancer and asthma. In response, the New York City (NYC) Health Department has conducted three descriptive studies. The first study in 1996, the second in 2000, and this study -- which examines cancer rates from 1995 to 2015, describe the incidence (new cases) of specific types of cancer in adults and total cancer among children living near the landfill compared with the rest of Staten Island. Given the community concerns about respiratory disease, this third study also looks at rates of asthma-related emergency department visits and hospitalizations, as well as deaths due to chronic lower respiratory disease, and deaths due to all causes other than injury (such as car crashes, suicides, poisonings, *etc.*).

Study Objectives

This study looked for patterns that could suggest a connection between living close to the landfill and health. We evaluated the strength of the evidence for increased risk of disease in the former Fresh Kills Landfill study area. If exposures from the former Fresh Kills Landfill increased health risks in nearby communities, we would expect to see consistent patterns in rates over time, as well as similar increases in rates in both men and women. Our objectives were to:

1. Compare the rates of new cases of total cancer and specific cancer types diagnosed from 1995 to 2015 among people residing in the 24 census tracts that make up the former "Fresh Kills Landfill study area" with rates in the rest of Staten Island for 1995-2015. For context, we also compared cancer rates in Staten Island with the rest of NYC.
2. Compare rates of asthma-related emergency department visits and hospitalizations in the neighborhoods near the former Fresh Kills Landfill study area, Staten Island as a whole, and the rest of NYC for 2012-2016.
3. Compare the rates of death due to causes other than injury or poisoning and death due to chronic lower respiratory diseases, among people living in the former Fresh Kills Landfill study area, in the rest of Staten Island and in the rest of NYC for 1995-2016.
4. Describe cancer incidence and mortality trends (over time) in the former Fresh Kills Landfill study area, the rest of Staten Island, and the rest of NYC.
5. Examine available data on known cancer risk factors, such as smoking, in neighborhoods next to the former Fresh Kills Landfill compared with Staten Island neighborhoods farther away and New York City.

Methods

The New York State (NYS) Cancer Registry provided data on total cancer and 17 specific types of cancer for adults by sex (e.g., male, female) and total cancer for children. We chose the 17 types based on their frequency in the general population, the potential for an association with landfill exposures, and community concern. The cancer types were: bladder, brain and nervous system, breast (women only), colon, Hodgkin lymphoma, kidney, larynx, leukemia, liver, lung, myeloma, non-Hodgkin lymphoma, pancreas, pharynx and oral cavity, prostate (men only), rectum, and thyroid.

Age-adjusted cancer incidence rates were calculated separately for men, women, and children in the former Fresh Kills Landfill study area, the rest of Staten Island and the rest of NYC for 1995-1999, 2000-2004, 2005-2009, and 2010-2015. The observed number of cancer cases in the Fresh Kills Landfill study area for 1995-2015 was compared with the number expected, based on rates for the rest of Staten Island. For cancer types identified as potentially elevated (using statistical criteria), we conducted a more rigorous proximity analysis over two periods (1995-2004 and 2005-2015). The proximity analysis examined new cases based on distance to the former landfill, assuming that if exposure to the landfill was causing cancer, one would see higher rates nearer the landfill than further away from it. We also conducted the proximity analysis for any cancers identified as elevated or any cancers of concern identified in the previous NYC Health Department studies.

Data on asthma-related emergency department visits and hospitalizations were obtained from the Statewide Planning and Research Cooperative System (SPARCS) on adults for 2012-2014 and on children aged 5 to 17 years for 2014-2016. Age-adjusted rates of death (excluding injuries) and death due to chronic lower respiratory disease for adults ages 17 and older by sex were obtained from the NYC Health Department's Bureau of Vital Statistics. Rates were compared within Staten Island.

Results

Total burden of cancer (1995-2015): The most common of the cancer types we studied were the same in the former Fresh Kills Landfill study area, the rest of Staten Island, and the rest of New York City for both men and women. In the former Fresh Kills Landfill study area, prostate, lung, and colon cancers accounted for more than 46% of cancers among men, while breast, lung, and colon cancers accounted for more than 49% of cancers among women.

Relative burden of cancer in the former Fresh Kills Landfill study area (1995-2015): Among children, there was no significant difference in cancer rates in the former Fresh Kills Landfill study area compared with the rest of Staten Island. In adults, there were statistically significant elevations in the former Fresh Kills Landfill study area in five cancer types – bladder, breast, kidney, non-Hodgkin lymphoma, and thyroid cancer – but within each cancer type, the trends did not show consistent increases for the study area over time or between men and women. In our proximity analysis of these five cancer types, as well as lung and total childhood cancer (included based on previous studies' recommendations), we found that none had significantly

elevated rates closer to the former landfill site during the earlier study period (1995-2004). In the later period (2005-2015), thyroid and bladder cancer rates were higher near the former landfill site.

Asthma: The neighborhoods around the former landfill had lower rates of asthma-related emergency department visits and hospitalizations than other parts of Staten Island for both children in 2014-2016 and adults in 2012-2014.

Deaths due to chronic lower respiratory disease and deaths due to causes other than injury: Chronic lower respiratory disease death rates were not elevated in the former Fresh Kills Landfill study area for men or women during the 1995-2015 study period. Among both men and women, rates of all deaths (excluding injury), were lower in the former Fresh Kills Landfill study area compared with the rest of Staten Island in 1995-2004, about the same in 2005-2009, and slightly elevated in 2010-2015.

Conclusion

This descriptive study found little evidence of an association between living close to the former Fresh Kills Landfill and cancer. The study described somewhat higher rates of bladder and thyroid cancers closer to the former landfill site only more recently. However, we were unable to identify any reasonable pathways for residents to be exposed to hazards in the landfill that are known or suspected to cause bladder or thyroid cancers. Now that the landfill is closed, chemical exposures from the former landfill are even less likely.

Variation in known risk factors and cancer detection rates across Staten Island are more plausible explanations than potential exposures from the landfill for the few elevations in rates we observed. Screening rates for thyroid cancer increased rapidly during the timeframe for this study, and a higher screening rate in the former Fresh Kills study area is one possible explanation for the elevation in thyroid cancer incidence. While it is not possible to know exact causes of individual cancer cases, smoking is the most important known risk factor for bladder cancer in the general population, and smoking rates are higher in Staten Island than in the rest of NYC. Therefore, we cannot rule out smoking patterns across SI as an explanation for the variation we observed in bladder cancer rates.

We did not find evidence for an association between living close to the former Fresh Kills Landfill and lower respiratory diseases. Asthma-related emergency department visits and hospitalizations were lower in the communities near the former landfill compared with other parts of Staten Island. Also, there were no elevations in chronic lower respiratory disease death rates and overall death rates were similar across Staten Island.

After reviewing the scientific literature and conducting three descriptive studies of health outcomes on Staten Island, we do not have evidence to conclude that exposures from the former Fresh Kills Landfill caused cancer, asthma, or death due to chronic lower respiratory disease or other causes (excluding injury) in the surrounding residential community.

Acknowledgments

Any study of this magnitude requires the work of many team members. The following people and their respective institutions made generous contributions of time and effort towards the completion of the *Descriptive Study of Cancer, Asthma, and Other Health Outcomes Around the former Fresh Kills Landfill, Staten Island*: Maria Schymura, Xiuling Zhang, and the staff members of the New York State Department of Health Cancer Registry for providing cancer incidence data; the members of the Staten Island Cancer and Ecological Study Scientific Advisory Committee (see Appendix A for membership roster) for their review and feedback on these analyses and report; the New York City Health Department Office of Vital Statistics: Mary Huynh and Gil Maduro for providing mortality data; the ICF Macro team: Jonathan Cohen, Sorina Eftim, Kaedra Jones, and Claudia Menashe; and the New York City Health Department study team: Christopher D'Andrea, Nancy Jeffery, Maureen Little, Wendy McKelvey, and Carolyn Olson.

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I. Introduction

A. Background

Previously 2,200 acres of swampland, the Fresh Kills Landfill in Staten Island, New York City (NYC), operated from 1948 to 2001 and was the world's largest landfill during much of that period. At its peak in 1991, approximately 29,000 tons of household rubbish were deposited daily in the landfill, ranging from food, paper, plastic and metal waste to potentially more hazardous items, such as televisions, engine oil, and solvents. New York State (NYS) ruled in 1996 that the Fresh Kills Landfill should stop accepting solid waste by the end of 2001. Landfill closure was temporarily suspended by the state after the World Trade Center (WTC) attack on September 11, 2001, to allow for the handling of materials from the WTC site.

Across the road from the Fresh Kills Landfill was the Brookfield Avenue Landfill, which closed in 1980, was fully remediated, and opened as a park in 2017.[1,2] Figure I-2 provides an overview of the history of the Fresh Kills Landfill area.[3] Following the Fresh Kills Landfill closure, NYC launched a plan to convert it into one of the largest parks in the City. Projected to take 30 years, the project includes capping the former landfill to prevent exposure to the buried municipal waste and its by-products, providing recreation space and returning much of the area to a natural environment with native animals and plants. Both while the landfill was operating and since its closure, residents of Staten Island have had concerns about potential environmental exposures resulting in adverse health impacts, such as cancer and asthma.

To address residential concerns, the New York City Department of Health and Mental Hygiene (NYC Health Department) conducted two prior descriptive studies looking at the incidence rates (new cases per 100,000 people) of specific types of cancer in both adults and children living near the Brookfield and Fresh Kills Landfills compared with the rest of Staten Island, as well as comparisons of Staten Island to the rest of New York City.[4,5] Previous studies used available data to describe possible associations between living near the landfill and cancer incidence in the context of overall cancer trends and known cancer risk factors. In this third study, we also examined cancer rates, as well as rates of asthma-related emergency department visits and hospitalizations and specific causes of death. The focus areas of the current study are the former Fresh Kills Landfill study area (the landfill and surrounding communities), Staten Island (excluding the former Fresh Kills Landfill study area), and NYC (excluding Staten Island) (Figure I-1).

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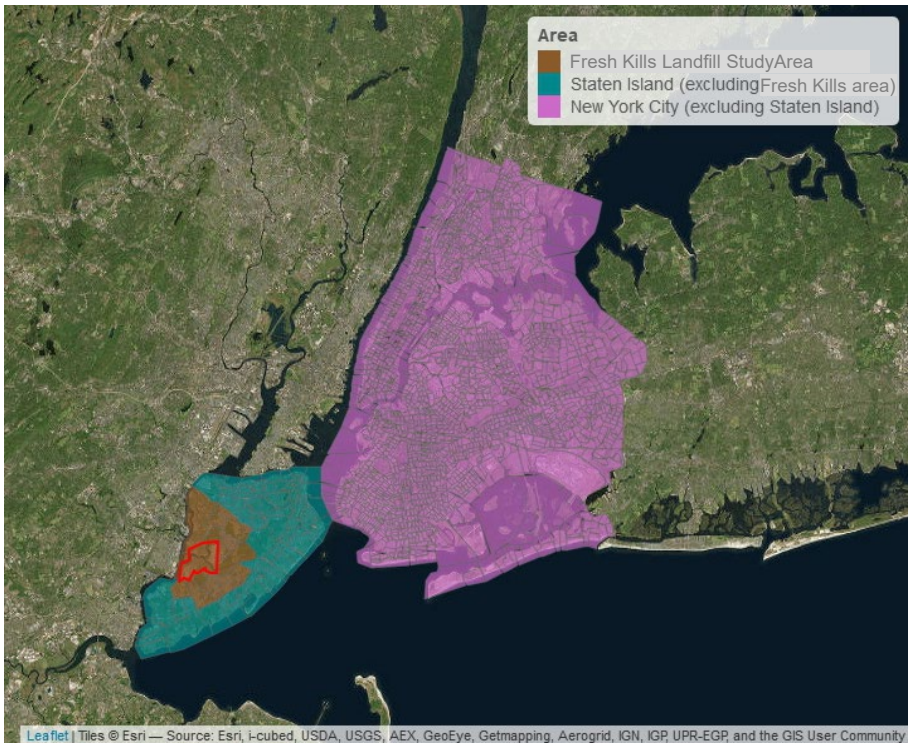
[1] New York State Department of Environmental Conservation (NYS DEC). 2017. Available at: https://www.dec.ny.gov/press/111121.html.
[2] New York City Department of Parks and Recreation (NYC Parks). 2019. Brookfield Park. Available at: https://www.nycgovparks.org/parks/brookfield-park
[3] Fresh Kills Park Alliance. 2018. Freshkills Park Timeline. Available at: http://timeline.freshkillspark.org
[4] NYCDOH. 1996. Staten Island cancer incidence study. New York: New York City Department of Health.
[5] NYCDOH. 2000. Study: Cancer incidence 1989–1992. New York: New York State Department of Health.

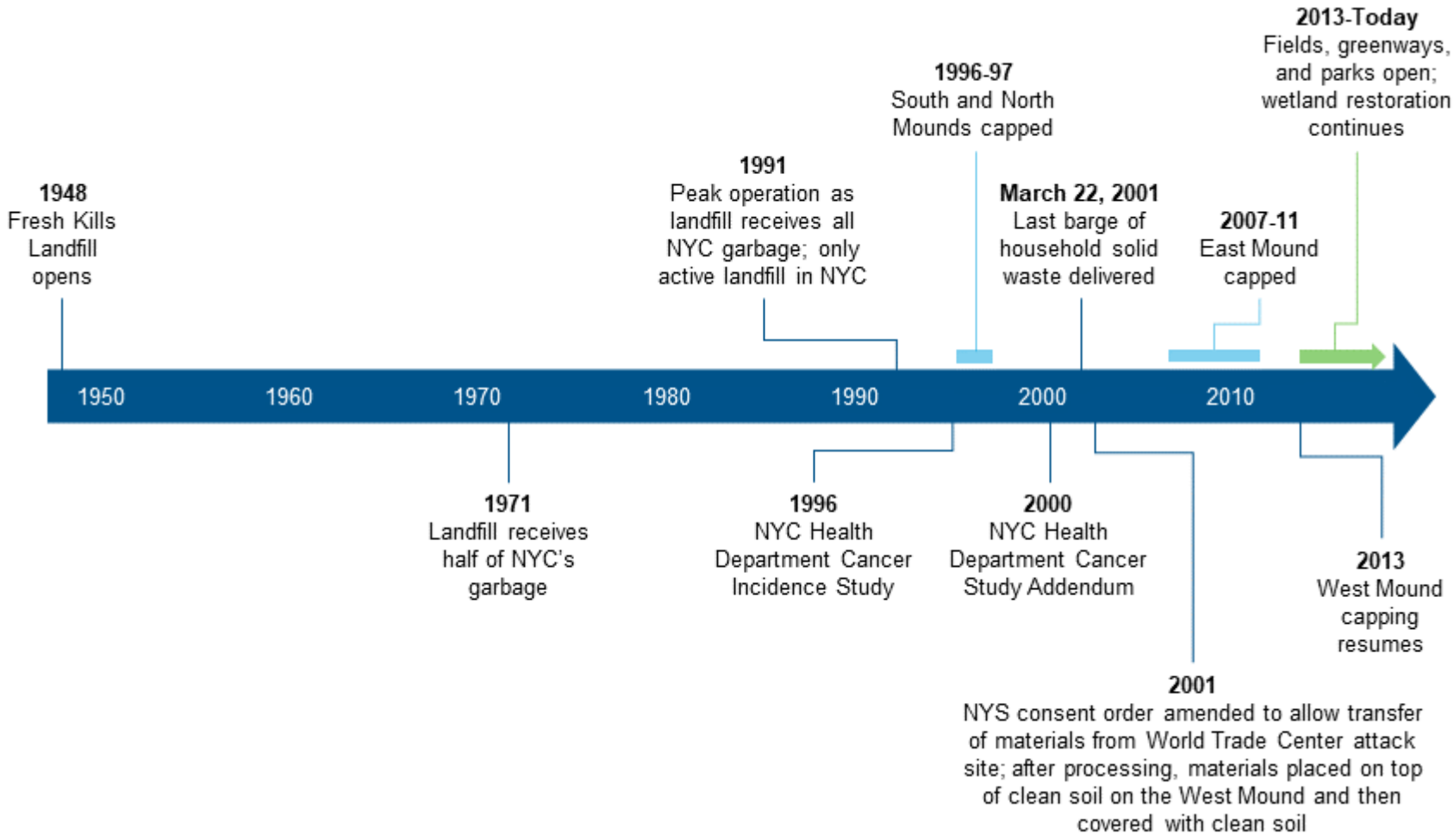
Figure I-1. The former Fresh Kills Landfill Study Area, Rest of Staten Island, and Rest of New York City



Red outline indicates the former Fresh Kills Landfill site.

It is important to understand what we can and cannot learn from descriptive studies like this study and the two previous NYC Health Department studies. By observing patterns of disease in different geographic areas (the former Fresh Kills Landfill study area, the rest of Staten Island and the rest of NYC) over time, we can draw inferences about potential risks from the former Fresh Kills Landfill. If exposures from the former landfill increased health risks in nearby communities, we would expect to see consistent patterns in disease and death rates over time, as well as similar increases or decreases in both men and women. Bear in mind, though, that most chronic diseases, including cancer and asthma, have a variety of causes and risk factors, including age, sex, race/ethnicity, family history, smoking, diet, exercise and exposure to certain chemicals. Because we could not control for differences in risk factors among populations living in these three geographic areas, we cannot know whether any observed increase in illness or death was associated with proximity to the landfill or was related to a higher prevalence of risk factors among people living close to the landfill, some of whom may have lived by the landfill for only a short time. As a result, our analyses will allow us to describe patterns of illness and death observed that might suggest a connection between the landfill and health outcomes, but will not allow us to determine causes of illness and death.

Figure I-2. Development, Use, and Transformation of Fresh Kills Landfill



B. Previous Research on Cancer, Asthma, and Mortality in Staten Island

Neither of the two studies previously conducted by the NYC Health Department found any statistically significant ($p<0.05$) elevations in cancer rates in the Fresh Kills Landfill area compared with the rest of Staten Island.[4,5] However, the 1996 study recommended further monitoring of kidney cancer, leukemia and lymphoma due to the observed moderate elevations. Continued monitoring of childhood cancer was also recommended due to community concern. The 2000 study Addendum recommended continued monitoring of leukemia and lymphoma, as well as central nervous system cancers (categorized in this study as brain and nervous system cancers). The 2000 study also evaluated trends in cancer incidence from 1978 to 1992. Breast and lung cancer rates in women in the Fresh Kills Landfill area increased, mirroring increases in Staten Island women overall.

For this third study, we conducted a review of current research on cancer and other health outcomes of interest in populations with potential landfill or hazardous waste site-related exposures in NYC, focused on residents in Staten Island. We also looked at studies assessing the health of workers at the Fresh Kills Landfill.

- The NYS Health Department found more frequent dermatologic, neurologic, hearing, and respiratory symptoms among workers at the Fresh Kills Landfill site than off-site workers.[6]
- Several studies found an association between respiratory symptoms and either working at (both before and after the WTC attack) or living near Fresh Kills Landfill.[6,7,8,9] For example, high percentages of physician-diagnosed asthma were reported in two studies of residents in close proximity to Fresh Kills Landfill, but similar results were seen among residents of the Staten Island north shore community.[7,8]
- Researchers have found significant associations between death rates due to breast cancer and birthplace on Staten Island, length of residence in Staten Island, and residence in Staten Island during puberty, although these studies did not document any associations

[6] Gelberg, K.H. 1997. Health Study of New York City Department of Sanitation Landfill Employees. Journal of Occupational & Environmental Medicine, 39(11): 1103-1110.
[7] Berger, S.A., Paul, J.A., White, M.C. 2000. Exploratory analysis of respiratory illness among persons living near a landfill. Journal of Environmental Health, 62: 19-23.
[8] Staines, A., Crowley, D., Bruen, M., O'Connor, P. 2004. Public health and landfill sites. Department of Public Health Eastern Regional Health Authority. Department of Public Health and Epidemiology at University College, Dublin.
[9] Cone, J.E., Osahan, S., Ekenga, C.C., et al. 2016. Asthma among Staten Island fresh kills landfill and barge workers following the September 11, 2001 World Trade Center terrorist attacks. American Journal of Industrial Medicine, 59: 795-804.

related to the landfill.[10,11,12]

- Statistically significant increases in the incidence of specific cancer types, including multiple myeloma, immunological, brain, kidney, and thyroid cancers, as well as non-Hodgkin lymphoma, were found among recovery workers at Fresh Kills Landfill who were sifting through debris after the WTC attack.[13,14]
- All-cause mortality rates were significantly lower than expected for rescue and recovery workers, and for non-rescue and non-recovery participants from the WTC Health Registry, compared with general population death rates. This study also looked at levels of exposures among registry participants and found some evidence of higher mortality risk for those with more intensive WTC-related exposure. This study did not look specifically at exposures related to the Fresh Kills Landfill.[15]

In summary, studies of individuals document higher cancer rates on Staten Island overall, and there is suggestive evidence for increased risk of a variety of adverse health outcomes among workers at Fresh Kills Landfill. However, we did not find individual-level studies that found an association between living near the landfill and cancer incidence. Studies of physician-diagnosed asthma reported similar high rates among Staten Island residents both near and distant (north shore) from the Fresh Kills Landfill.[16]

WTC rescue workers and workers on the former landfill site are not the focus of this study, but it is likely that our study population includes WTC workers and those who were exposed to the WTC attack in lower Manhattan. Because we did not have data on WTC experience for residents in the study or comparison areas, we cannot rule out the possibility that WTC-related exposures are influencing some of the patterns we observe in this study.

We also considered available information on potential exposures from the former Fresh Kills Landfill. Any exposure to nearby residents would have to occur through contact with one or more of four possible environmental media: air, groundwater, soil, and surface water. Before Fresh Kills Landfill's closure, nearby residents may have been exposed to odors or airborne

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[10] Gerstle, D., Levine, A.M., Silich, R.C., et al. 2003. Staten Island breast cancer project: Occupation, length of residence and mortality risk. APHA Annual Meeting.
[11] Gerstle, D. 2013. Staten Island breast cancer research initiative: Neighborhoods and length of residence on Staten Island, puberty and breast cancer mortality risk with respect to environmental contamination sites. APHA Annual Meeting.
[12] White, K. 2013. Staten Island breast cancer research initiative: Birthplace, length of residence on Staten Island and accessibility to comprehensive cancer control centers and breast cancer mortality in older females. 141st APHA Annual Meeting (November 2-November 6, 2013).
[13] Gelberg, K.H. 2011. World Trade Center responder fatality investigation program. Report by the New York State Department of Health.
[14] Kleinman, E.J., Christos, P.J., Gerber, L.M., et al. 2015. NYPD cancer incidence rates 1995–2014 encompassing the entire World Trade Center cohort. Journal of Occupational and Environmental Medicine, 57: e101-e113.
[15] Jordan, H.T., Brackbill, R.M., Cone, J.E., et al. 2011. Mortality among survivors of the Sept 11, 2001, World Trade Center disaster: Results from the World Trade Center Health Registry cohort. The Lancet, 378: 879-887.
[16] Berger, S.A., Paul, J.A., et al. 2000. Exploratory analysis of respiratory illness among persons living near a landfill. Journal of Environmental Health, 62: 19-23.

pollutants, such as solvents and polycyclic aromatic hydrocarbons. These are common contaminants from many sources, including industrial operations in Staten Island and New Jersey. In 2000, ATSDR evaluated what was considered at that time one of the largest sets of outdoor air monitoring data for a municipal solid waste landfill.[17] ATSDR concluded that levels of airborne contaminants thought to originate from the landfill did not exceed levels considered "unhealthy" or "unsafe" and presented no apparent public health hazard. Today, landfill gases are controlled by a system that captures the gas for generating electricity, and any exposures to airborne contaminants would be unlikely.

The three of the four landfill mounds have been completely capped, with the final mound covered and due to be completely capped in 2021, with a system of physical barriers topped by two feet of clean soil, minimizing potential exposure to soil contaminants.[18] Groundwater has not been used for drinking water since 1970 in Staten Island, so residents would not have been exposed to any potential landfill contaminants through drinking water for almost 50 years. Although studies conducted by ATSDR found contaminants that might have originated at the landfill in nearby surface waters and sediments, the levels were not considered hazardous to public health.[16,19,20] Furthermore, prolonged direct contact with these contaminated surface waters was unlikely, because recreational use of these waters was historically limited and not supported by the NYS Department of Environmental Conservation.[21,22,23]

C. Study Development

This *Descriptive Study of Cancer and Other Health Outcomes Around the former Fresh Kills Landfill, Staten Island* further extends the findings of the previous NYC Health Department *Staten Island Cancer Incidence Study* (March 1996) and its addendum (March 2000) by evaluating cancer incidence from 1995-2015, as well as looking at other health outcomes, in the Staten Island community surrounding the former Fresh Kills Landfill, the rest of Staten Island, and the rest of NYC. The study's methods, analysis and report were designed with input and guidance from our Scientific Advisory Committee (SAC – see Appendix A for participant list). Results from both the previous study and its addendum were also reviewed by expert panels and

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[17] Agency for Toxic Substances and Disease Registry (ATSDR). 2000. Petitioned Public Health Assessment Fresh Kills Landfill Staten Island, Richmond County, New York EPA Facility ID: NYD980506943.
[18] The Freshkills Park Alliance: https://freshkillspark.org/the-park/landfill-engineering.
[19] Agency for Toxic Substances and Disease Registry (ATSDR). 1998. Health Consultation Fresh Kills Landfill, Staten Island, Richmond County, New York CERCLIS No. NYD980506943.
[20] Agency for Toxic Substances and Disease Registry (ATSDR). 1998. Health Consultation Fresh Kills Landfill, Staten Island, Richmond County, New York CERCLIS No. NYD980506943.

SACs, which recommended that NYC Health Department continue to monitor cancer and disease incidence data when available. Now that sufficient additional years of data are available, this study updates and expands upon the original analyses.

II. Methods

A. Objectives

While this study mirrors the overall analytic approach used in the previous NYC Health Department study and its addendum to allow for comparison, it incorporates more advanced statistical methods and considers two additional health outcomes – deaths due to all causes other than injury (such as car crashes, suicides, poisonings, *etc.*) and specifically from chronic lower respiratory disease, and asthma-related emergency department visits and hospitalizations.

The objectives of this study were to:

1. Compare the rates of new cases of total cancer and specific cancer types diagnosed from 1995 to 2015 among people residing in the 24 census tracts that make up the "former Fresh Kills Landfill study area" with rates in the rest of Staten Island for 1995-2015. For context, we also compared cancer rates in Staten Island with the rest of NYC.
2. Compare rates of asthma-related emergency department visits and hospitalizations in the neighborhoods near the former Fresh Kills Landfill, Staten Island as a whole, and the rest of NYC for 2012-2016.
3. Compare the rates of all death (excluding injury) and death due to chronic lower respiratory diseases, among people living in the former Fresh Kills Landfill study area, in the rest of Staten Island and in the rest of NYC for 1995-2015.
4. Describe cancer incidence and mortality trends (over time) in the former Fresh Kills Landfill study area, the rest of Staten Island, and the rest of NYC.
5. Examine available data on known cancer risk factors, such as smoking, among residents in South Staten Island neighborhoods next to the former Fresh Kills Landfill, North Staten Island neighborhoods and in the rest of NYC.

B. Fresh Kills Landfill Study Area and Comparison Areas

We defined the area around the former landfill (Fresh Kills Landfill study area) for cancer and deaths using the same 24 census tracts as used in the previous NYC Health Department studies (Appendix B). For analyses of asthma-related emergency department visits and hospitalizations, we defined the Fresh Kills Landfill area using data for neighborhood tabulation areas (NTAs), which are different groupings of census tracts. A description and list of NTAs that overlap with the former Fresh Kills Lanfill study area are in Appendix C (Figure C-1). Risk factor data were available in two groups of ZIP Codes defined by the United Hospital Fund for north and south

Staten Island, with the former Fresh Kill Landfill study area encompassed in the southern neighborhood (Appendix C, Figure C-2). Finally, demographic data were available for ZIP Code 10314, which contains nearly the entire former Fresh Kills Landfill study area (Appendix C, Figure C-3).

For all three health outcomes, we compared the Fresh Kills Landfill area with the rest of Staten Island. We compared cancer and asthma health care use rates for Staten Island overall with those for the rest of New York City. We also looked at trends in death rates for the rest of New York City. The three areas included in this study are illustrated in Figure I-1. The Fresh Kills Landfill study area is shaded in brown (with the former Fresh Kills Landfill outlined in red), and the two comparison areas are shaded in green and purple, respectively.

In the two previous NYC Health Department studies, we used a comparison area that was similar to the former Fresh Kills Landfill study area based on race/ethnicity and income distribution: Bay Ridge, Brooklyn, and Flushing, Queens. However, when looking at the 2010 United States (U.S.) Census data, neither those neighborhoods nor any others in NYC are now demographically comparable to the former Fresh Kills Landfill study area (see Appendix I for comparison data). Our SAC concluded that including a comparison neighborhood outside Staten Island would not add value to this study.

C. Health Outcomes of Interest and Sources of Data

Our selection of the primary health outcomes of cancer incidence, causes of death, and asthma was informed by the previous NYC Health Department studies, reports from elected officials, concerns expressed by some residents of Staten Island, and the SAC.[24] Table II-1 provides an overview of the health outcomes selected, the data source and available years of data. Additional information on demographic data used in this study can be found in Appendices D and F.

Table II-1. Data Sources Used for this Study.

Outcome/Input	Years	Data Source
Cancer • Total cancer • Specific cancers (Figure II-1)	1995-2015	NYS Department of Health Cancer Registry
Causes of Death - counts and age-adjusted rates • All mortality excluding injury • Chronic lower respiratory disease	1995-2015 overall and in four periods: 1995-1999, 2000-2004, 2005-2009, 2010-2015	NYC Health Department, Bureau of Vital Statistics
Asthma • Hospitalizations • Emergency department visits	2012–2014 (adults); 2014-2016 (children)	NYS Department of Health Statewide Planning and Research Cooperative System (SPARCS)

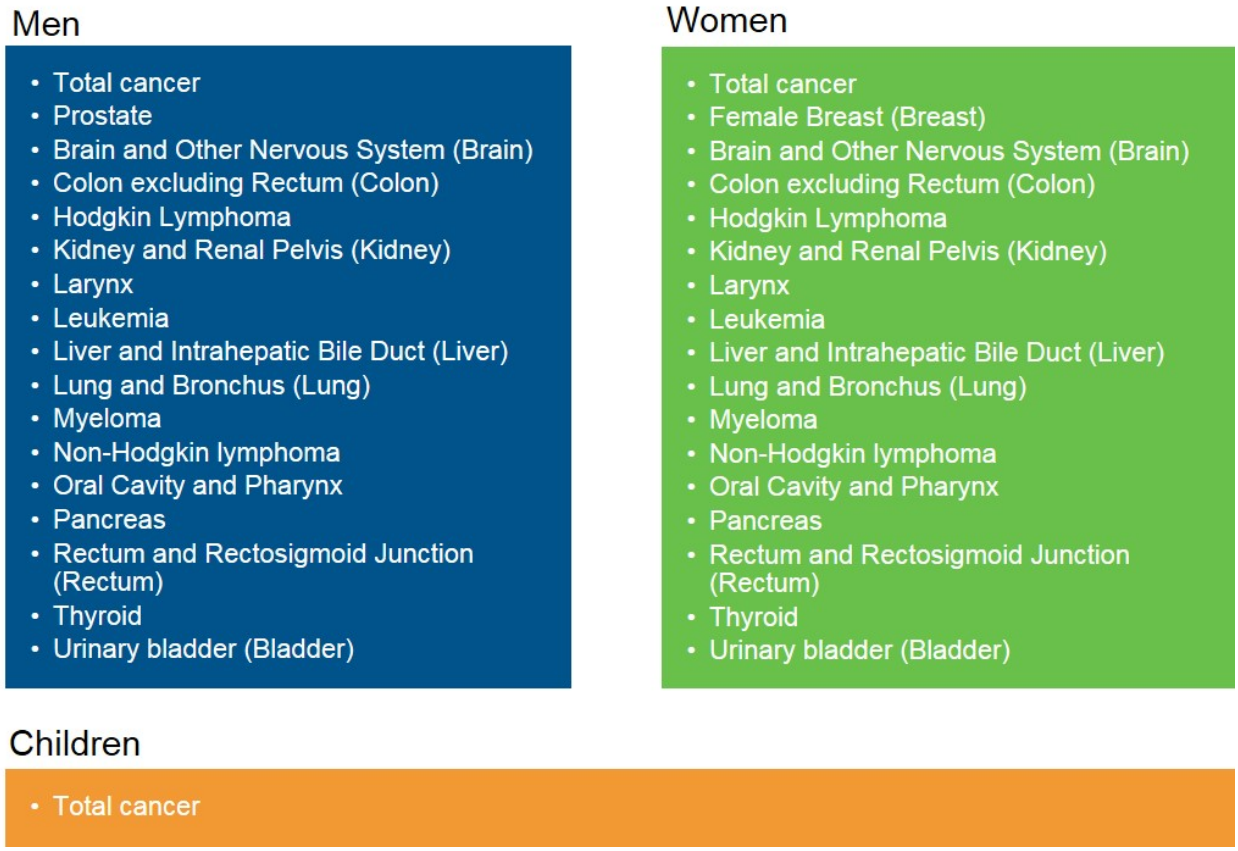
[24] Borelli, J.C. 2017. A report on the health impacts from the proximity of residential populations to Fresh Kills landfill. Available at: www.council.nyc.gov/district-51/

Population Estimates by age and sex	1995-2015 overall and in four periods: 1995-1999, 2000-2004, 2005-2009, 2010-2015	NYS Department of Health Cancer Registry, based on U.S. Census 1990, 2000, and 2010
Demographics and Risk Factors	Demographics: 2010-2016 Income: 1995-2002, 2003-2011, 2012-2015 Risk factors: 2002-2016	2012-2016 American Community Survey 2006-2010 American Community Survey (see Appendix D for additional details on data calculation) NYC Department of Health and Mental Hygiene Community Health Survey
Shape files representing geographic areas of the study	2010	Census Tracts: Department of City Planning (DCP) from NYC OpenData; Landfill areas: Department of Parks and Recreation (DPR) 2013 from NYC OpenData. All centroids (a shape's central point) calculated using ArcGIS.

1. Selection of Specific Cancers for Analysis

The specific cancers selected for this study mirror those from the two previous NYC Health Department studies: total cancer, 17 specific cancer types by sex, and three specific types for children (14 years or younger) (Figure II-1). Because of the small number of childhood cancers, only total cancer for children is presented in this report. These cancer types were selected for two reasons: 1) residents were concerned that there may have been an unusually high incidence; or 2) these cancers have been shown to be related to environmental exposures.

Figure II-1. Specific Cancers Selected for this Study



D. Analysis

Details on all statistical analyses are provided in Appendix D, with a brief description for each set of outcomes here.

Cancer: We calculated age-adjusted cancer incidence rates – the number of new cancer cases per 100,000 persons – for men and women in the former Fresh Kills Landfill study area, the rest of Staten Island, Staten Island overall, and the rest of NYC for the entire period (1995-2015) and by four intervals (1995-1999, 2000-2004, 2005-2009, 2010-2015). We then compared the rates in these areas using a statistic called the standardized incidence ratio (SIR). The SIR is the number of observed cancer cases divided by the number of cases we would expect in an area if it had experienced the same rates as the comparison area. A SIR greater than 1.0 indicates more cases than expected. Elevated differences in cancer incidence rates were defined as:

- Slight elevation: SIR greater than 1.05 with a *p*-value of less than 0.05
- Moderate elevation: SIR greater than or equal to 1.25 with a *p*-value of less than 0.05

Our use of SIRs is an important difference from the prior NYC Health Department studies, which used age-adjusted rate ratios. SIRs may provide greater statistical power to detect elevations in this study.

We also conducted a more rigorous analysis of specific cancers that were selected for further investigation (see Appendix D for selection process). We modeled rates for two periods, 1995-2004 (earlier) and 2005-2015 (later), as a function of the distance between the center of each of the 107 census tracts on Staten Island and the center of the former landfill. We separated the study periods into earlier and later to address concerns that associations may have changed over time, while maintaining large enough numbers to assess differences. This "proximity analysis" is based on methods described by Wakefield and Morris.[25] The approach uses a statistical model that has a term called "alpha" that represents the estimated impact of living closer to the landfill. We considered there to be evidence for elevated cancer rates in census tracts closer to the landfill when the probability of alpha greater than zero was more than 95%. We estimated the range of excess cases of cancer that could plausibly be associated with living closer to the landfill, along with a 95% credibility interval that represents the uncertainty of the estimate (Appendix F). If there was no elevation in cancer risk closer to the landfill – or if the risk was lower closer to the landfill, the estimate of excess cases would be zero or a negative number.

The proximity analysis controlled for income at the census tract level, which may help adjust for cancer risk factors related to income. If exposures from the landfill were causing cancer, we would expect any associations with proximity to be at least as strong in the earlier period (1995-1999) when the landfill had been operating for more than 40 years as found in the later period. We considered evidence for a landfill effect to be weaker when the association with cancer in earlier years was not at least as strong as in the later period.

Causes of Death: We calculated age-adjusted mortality rates for men and women in the former Fresh Kills Landfill study area, the rest of Staten Island, and the rest of NYC for the four time intervals between 1995 and 2015. We then compared the rates in each period using mortality rate ratios (MRR). Similar to the SIRs for cancer, a MRR greater than 1 indicates more deaths than expected, and elevations significant at *p*-value less than 0.05 and MRR greater than 1.05 were flagged as slightly elevated, and those greater than or equal to 1.25 as moderately elevated.

Asthma: We compared age-adjusted rates of asthma-related emergency department visits and hospitalizations among adults and crude rates among children living in neighborhoods around the Fresh Kills Landfill area with Staten Island neighborhoods farther away and with other boroughs. We limited comparisons to the most recent years of data available, because asthma-related use of the health care system does not involve a latency period, making recent data most relevant to assessing potential impacts from the former landfill today. Because of changes in diagnostic coding systems in classifying adult asthma, data are not comparable before and after 2015 and are unavailable for 2015, so the most recent data are from 2012-2014. There were no changes to diagnostic coding of asthma for children, so the most recent data are from 2014-2016.

[25] Wakefield, J.C and Morris, S.E. 2001. The Bayesian modelling of disease risk in relation to a point source. Journal of American Statistical Association, 96(435): 77-91.

1. Limitations

Our analyses were limited by several factors. As already discussed, we were unable to consider the many individual risk factors that could influence disease patterns, beyond distance from the potential environmental risk. Since we were unable to control for known risk factors, we cannot rule out reasons other than the landfill as explanations for the appearance of higher rates of any cancers or other health outcomes in the former Fresh Kills Landfill study area.

We were also unable to account for changes in how cancer was diagnosed during the period evaluated in this study (1995-2015). Awareness about benefits to finding cancer early, improved therapies, and access to care can lead to increased detection – more cancer cases found – and some cancer detection rates did increase during the study period. Increased awareness and use of cancer screening can create the false appearance of increased cancer rates in some areas, and cancer screening rates may have increased more in Staten Island than the rest of NYC and by varying amounts across Staten Island neighborhoods, influencing cancer rate patterns.

Investigation of potential environmental causes of health outcomes is challenged by two additional factors beyond the scope of our analysis: people moving from one location to another and disease latency – the time period that passes between being exposed to something that can cause disease and having symptoms. Our data are based on where someone was living at time of cancer diagnosis, asthma health care use, or death. Population estimates, changes in where people lived, and the underlying social factors that go along with population changes not only play a significant role in the calculation of cancer incidence and other health outcome rates, but also in the observed variation in rates across NYC. Also, many cancers have long latency periods – 20 years or more – between exposure to a carcinogen and clinical detection of disease symptoms. Moreover, individuals may change their residence, behaviors and work, making it difficult to link environmental exposures with diagnosed cancer.

In addition, we did not have any information on either group- or individual-level environmental exposures – whether from the former landfill or other sources, such as the Brookfield landfill, industrial areas, the WTC attack, or work-related exposures. Assessing exposure was beyond the scope of this study, but we considered available information on potential ways people could be exposed to known risk factors to provide context for our findings.

III. Findings

We present our findings on associations between living near the landfill and each health outcome (cancer, mortality, and asthma health care use). Also considered are evidence from other studies and the limitations of a descriptive approach to studying possible risk of exposures from the former landfill without considering known risk factors that could influence our findings. Supplementary results can be found in Appendix E and Appendix F (cancer); Appendix G (mortality); and Appendix H (asthma).

Fresh Kills Landfill Study Area Population: Residents in the former Fresh Kills Landfill study area are just slightly older than residents in Staten Island overall. The study area has a median age of 40 years with 14% of residents aged 65 and older, compared to a median of 38 years and 12.7% older adults in Staten Island overall. The former Fresh Kills Landfill study area has a higher proportion of White residents, a lower proportion of Black and Latino residents, and a higher or similar proportion of Asian residents compared with Staten Island overall and NYC overall. The study area has more foreign-born residents than Staten Island overall, but fewer foreign-born residents than NYC overall. Although the proportion of residents with a bachelor's degree is similar between the study area, Staten Island, and NYC, the proportion of residents living below 100% of the Federal Poverty Level was much lower in both the former Fresh Kills Landfill study area (9.4% in 2015) and Staten Island overall (12.9%) compared to New York City overall (20.3%).

Staten Island residents, including those in the study area, have been consistently more likely to smoke than NYC residents overall since NYC Health Department surveys began collecting this information in 2002. Similarly, the residents of the former Fresh Kills Landfill study area and Staten Island overall are more likely to be obese than NYC residents overall. Rates of fruit or vegetable consumption, physical activity, and having a personal doctor or physician were all higher in the study area compared with Staten Island overall and NYC overall. Breast cancer screening rates fluctuated between 2002 and 2014 in the study area, Staten Island, and NYC overall.

Additional information on the prevalence of various risk and demographic factors of interest related to the former Fresh Kills Landfill study area, Staten Island overall, and NYC populations can be found in Appendix I, along with an overview of individual and environmental risk factors currently linked to specific cancers of interest.

A. Cancer

The most common of the cancer types we studied were the same in the former Fresh Kills Landfill study area, the rest of Staten Island, and the rest of New York City for both men and women. In the former Fresh Kills Landfill study area, prostate, lung, and colon accounted for more than 46% of cancers among men, while breast, lung and colon accounted for more than 49% of cancers among women.

We found no consistent increases or decreases from 1995 to 2015 in overall cancer incidence rates for men (Figure III-1) or women (Figure III-2) in the former Fresh Kills Landfill study area, the rest of Staten Island, or the rest of NYC. Among children (Figure III-3), trends were suggestive of a slight increase overall, but only the rest of NYC had a statistically significant increase in rates of childhood cancer incidence.

Figure III-1. Trends in Total Cancer in Men (1995-2015)

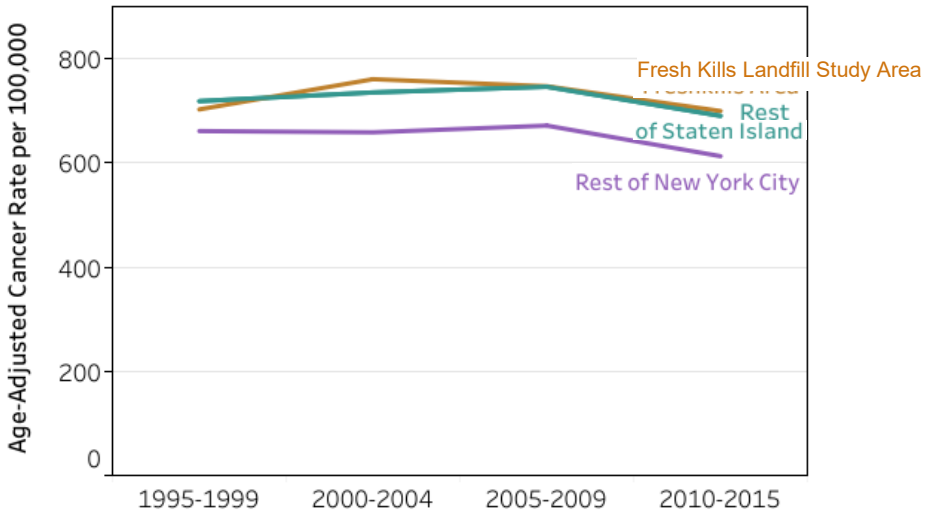


Figure III-2. Trends in Total Cancer in Women (1995-2015)

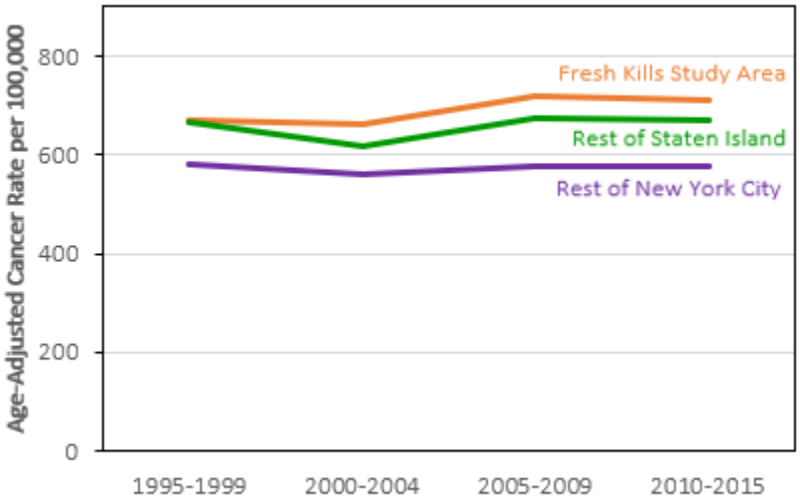


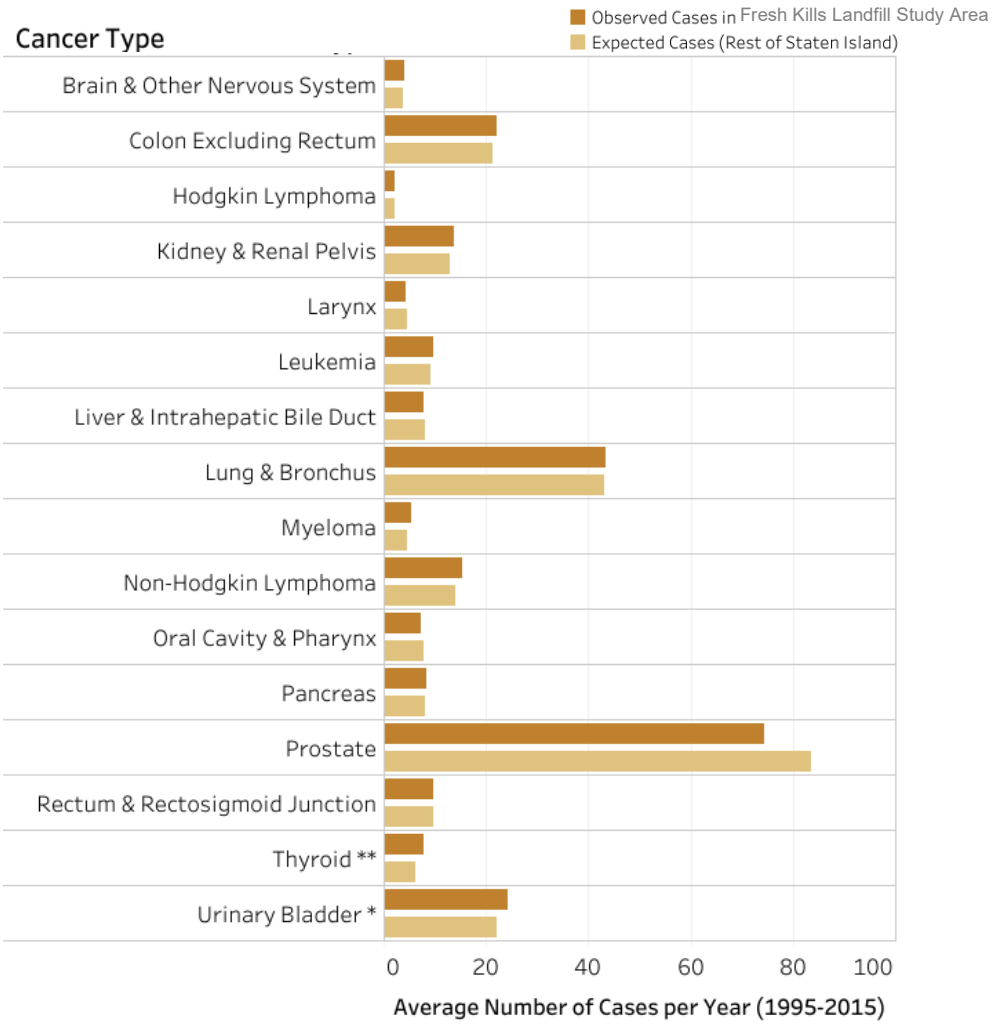
Figure III-3. Trends in Total Cancer in Children (1995-2015)

Trend results across all cancer types assessed in this study are available in Appendix E. Only colon cancer declined significantly from 1995 to 2015 across all three geographic areas for both men and women, while thyroid cancer increased across all three areas for both.

We started our cancer analyses by looking at Staten Island versus the rest of NYC. Staten Island had slightly elevated rates of total cancer for men and women compared with the rest of NYC (SIR=1.11 and 1.16, respectively). Staten Island had slight or moderate elevations for multiple specific types of cancers including: bladder, breast, colon, larynx, liver, lung, leukemia, Hodgkin lymphoma, myeloma, oral cavity and pharynx, pancreas, prostate, thyroid in either or both men and women, but no statistically significant differences for children.

In the former Fresh Kills Landfill study area, total cancer rates in women were slightly elevated compared with the rest of Staten Island for 1995-2015 overall, but we found no significant elevations for men or children. The SIRs for men, women and children were 1.00 (p=1.00), 1.05 (p<0.01), and 1.11 (p=0.36), respectively. We also observed elevations of several types of cancers in the former Fresh Kills Landfill study area. Over the 21-year period, bladder cancer was slightly elevated in men, while breast cancer and non-Hodgkin lymphoma were slightly elevated in women. Only thyroid cancer had elevations for both men (moderate) and women (slight). We compared the average annual number of observed cases with the expected number for each specific cancer in men (Figure III-4), women (Figure III-5), and children (Figure III-6) in 1995-2015 overall. Detailed findings can be found in Appendix E; they show inconsistencies in the patterns of elevations across the four periods and between men and women.

Figure III-4. Average Annual Counts of Observed and Expected Cases of Specific Cancers Among Men in the Fresh Kills Landfill Study Area (1995-2015)



*Slight elevation: SIR>1.05 and p<0.05; **Moderate elevation: SIR≥1.25 and p<0.05

Figure III-5. Average Annual Counts of Observed and Expected Cases of Specific Cancers Among Women in the former Fresh Kills Landfill Study Area (1995-2015)

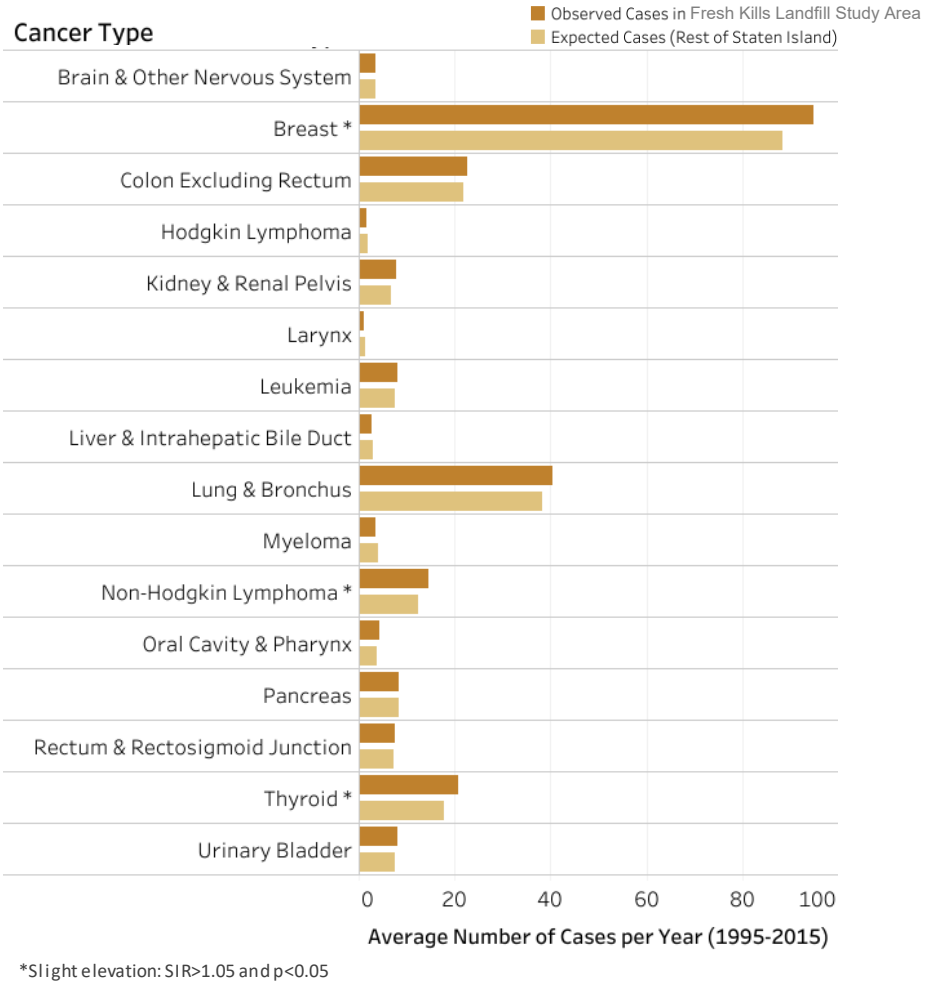
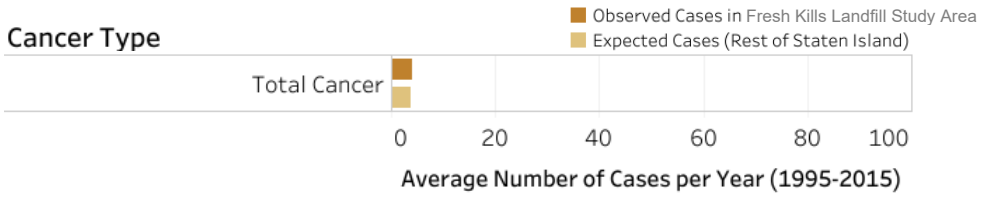


Figure III-6. Average Annual Counts of Observed and Expected Cases of Total Cancer Among Children in the former Fresh Kills Landfill Study Area (1995-2015)



We took an inclusive approach to selecting which cancers to examine using the proximity analysis described in Appendix D. For inclusion in the proximity analysis, the cancer type either was at least slightly statistically elevated with a *p*-value of less than 0.10 for the 21-year period or was highlighted in the previous NYC Health Department study and its addendum (see Appendix D for full criteria). Thus, we selected bladder, breast (women only), kidney, lung, and thyroid cancers, non-Hodgkin lymphoma, and total cancer in children (see quantitative results in Appendices E and F).

In addition to our statistical models of cancer incidence by proximity to the landfill, we also reviewed available information on known risk factors for each cancer type. We summarize below our findings for each of the seven selected cancers.

1. Bladder Cancer

Bladder cancer occurs much more frequently in men than women, and rates are generally lower than rates of more common cancers. Compared with the rest of NYC, bladder cancer rates were moderately elevated among both men and women on Staten Island (Figure III-7 and Figure III-8). In the former Fresh Kills Landfill study area, rates were slightly elevated among men but not women relative to the rest of Staten Island, and the pattern of elevations among men was inconsistent across consecutive periods from 1995 to 2015.

Figure III-7. Trends in Bladder Cancer in Men (1995-2015)

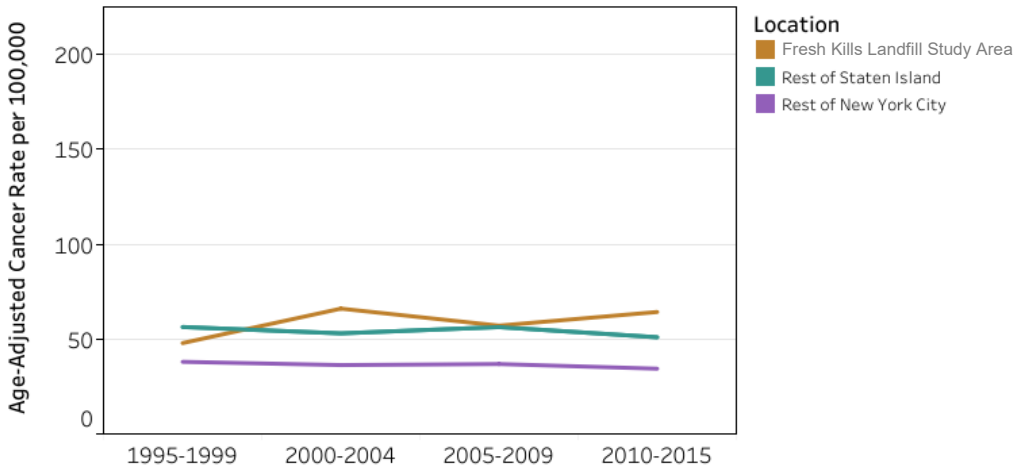
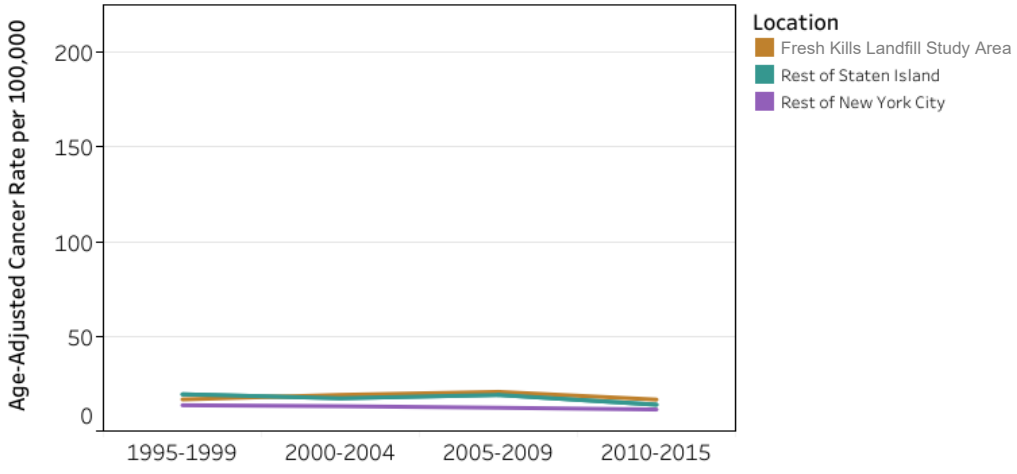


Figure III-8. Trends in Bladder Cancer in Women (1995-2015)



While it is not possible to know exact causes of individual cancer cases, smoking is the most important known risk factor for bladder cancer in the general population, and smoking rates are

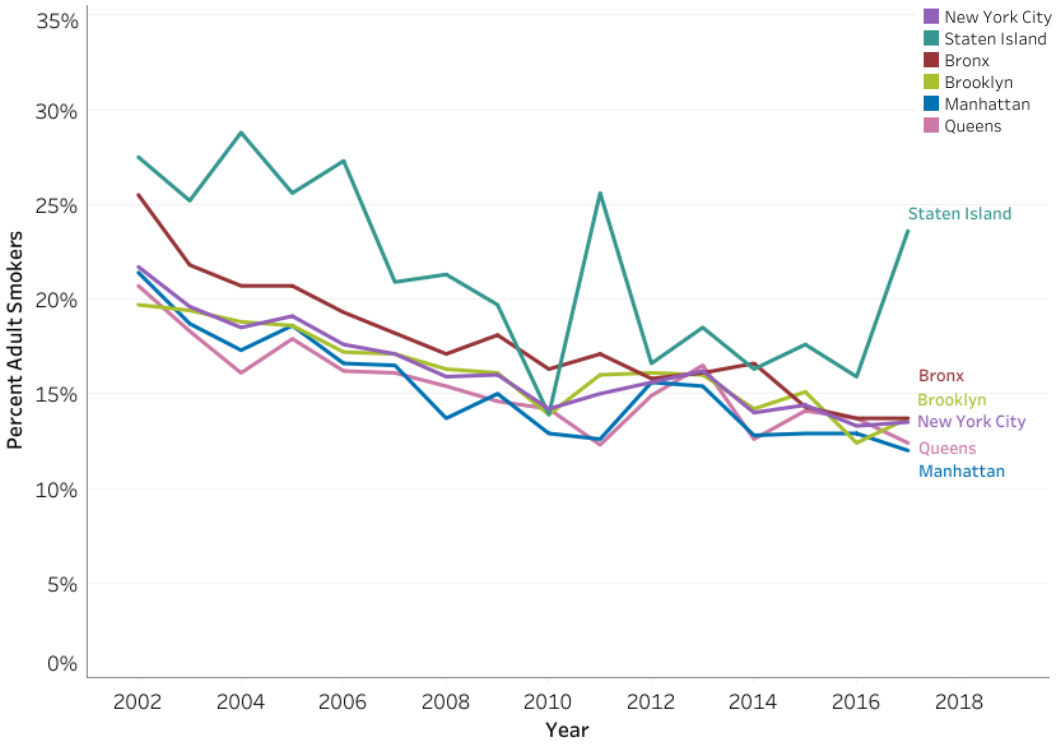
higher in Staten Island than in the rest of NYC. Additional risk factors for bladder cancer include use of some medicines and herbal supplements, not drinking enough fluids, and radiation to the pelvis – none of which are directly related to potential landfill exposures. Exposure to arsenic in drinking water is a risk factor for bladder cancer, but there was no pathway of exposure to contaminated drinking water. During the study period, Staten Island drinking water came from upstate New York and did not contain elevated concentrations of arsenic.

Although exposure to high concentrations of certain industrial dye chemicals is also a risk factor for bladder cancer, we have no indication that such chemicals were present at the former landfill. Furthermore, studies linking these dye chemicals to increased risk of bladder cancer were conducted among dye workers exposed to higher concentrations and over longer time periods than could have conceivably occurred to nearby residents.

Results from the proximity analysis did not suggest elevations during 1995-2004, but did suggest that in more recent years, bladder cancer rates were higher near the landfill. We estimated that the number of cases that could have plausibly been associated with living near the landfill between 2005 and 2015 ranged from two fewer cases each year to fifteen additional cases each year. On average, there could have been seven excess cases each year.

The two previous NYC Health Department studies that looked at bladder cancer incidence rates before 1993 found non-significant elevations in the Fresh Kills Landfill area compared with the rest of Staten Island, but rates were unstable over time and between men and women. Since smoking is the most important risk factor for bladder cancer, and smoking rates are higher in Staten Island than in the rest of NYC (Figure III-9), smoking patterns within (or across) Staten Island are likely to contribute at least somewhat to variation in bladder cancer rates. Because both our study and the two previous studies were unable to control for this and other important risk factors, we cannot rule them out as explanations for the patterns we observed.

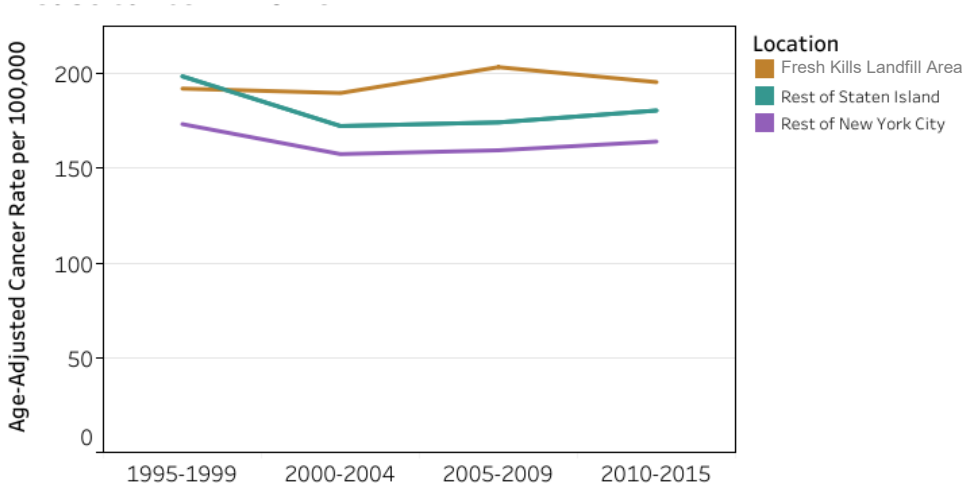
Figure III-9. Smoking Trends in Staten Island and New York City (2002-2017)



2. Breast Cancer (women only)

Breast cancer is the most common cancer in American women, except for skin cancers, and is the second leading cause of cancer death in women (after lung cancer). Breast cancer rates on Staten Island have been about 8% to 13% higher than the rest of NYC for many years. Rates of breast cancer among women living the former Fresh Kills Landfill study area were slightly elevated compared with the rest of Staten Island for 2000-2015, but not during 1995-1999. This difference weakens evidence for a landfill effect, because we would expect any effect from landfill-related exposures to be at least as strong earlier as later in the study period. (Figure III-10).

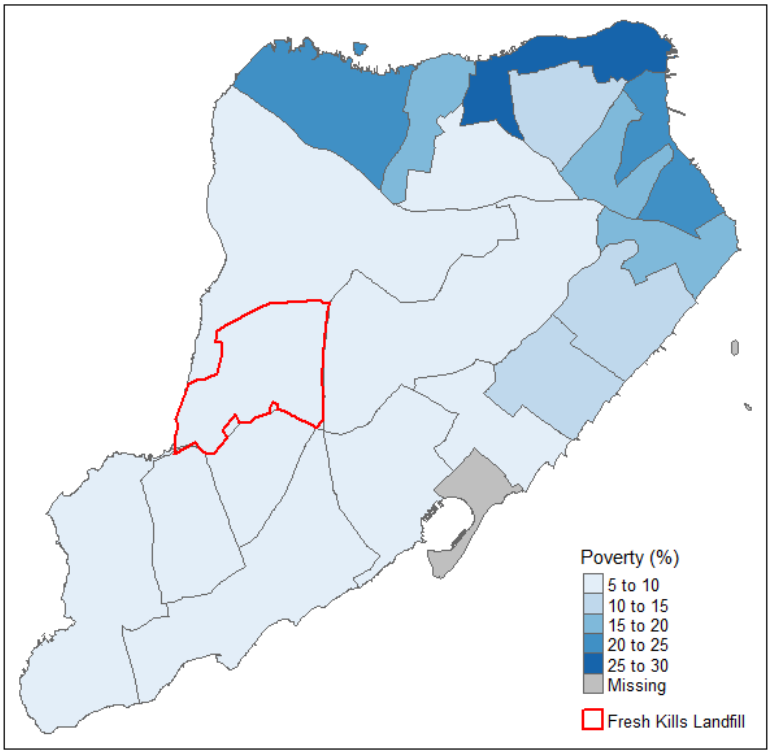
Figure III-10. Trends in Breast Cancer in Women (1995-2015)



Some risk factors for breast cancer are inherited – like family history and certain genes. Risk factors related to lifestyle include drinking alcohol, being overweight or obese, not being physically active, not having children (or having them at a later age), not breastfeeding, and use of certain hormones. We were unable to control for these risk factors in our analyses of the former Fresh Kills Landfill study area, but in the proximity analysis we controlled for income, which has been shown to be a proxy for some of these risk factors (*e.g.,* having children at a later age). We note that area-level income in the area around the landfill is relatively high compared with NYC overall (Figure III-11; Appendix I). In the six NTAs that overlap with the former landfill site, the percent of residents living in poverty ranges from 5.5 to 9.5%, compared with 20% of NYC residents. Unemployment is also lower in this area.[26] Controlling for income lessened the association with breast cancer, which suggests the presence of associated factors that are not related to the landfill.

[26] New York City Community Health Portal (NYC CHP). 2018. http://a816-dohbesp.nyc.gov/IndicatorPublic/VisualizationData.aspx?id=103,4466a0,109,Summarize

Figure III-11. Poverty in Staten Island Neighborhood Tabulation Areas – Percent (2013-2017)



Many studies have investigated potential effects of environmental exposures on breast cancer. At this time, the bulk of scientific evidence does not suggest any clear links. In other words, existing knowledge about the causes of breast cancer does not provide any reasonable explanation for how potential exposure to a landfill could cause this disease. Results from the proximity analysis did not suggest that breast cancer rates were higher near the landfill, similar to findings from the previous two NYC Health Department studies.

3. Kidney Cancer

Kidney cancer is an uncommon cancer, which occurs more frequently in men than in women. Kidney cancer rates were slightly elevated among women and moderately elevated among men in Staten Island compared with the rest of NYC. Over the 21-year period, slight elevations were seen among women in the former Fresh Kills Landfill study area versus the rest of Staten Island (Figure III-12), but the slight elevation for 1995-2015 overall fell short of statistical significance (p=0.08). Among men, there was no elevation for the entire timeframe and only one five-year period showed a slight elevation compared with the rest of Staten Island (Figure III-13).

Figure III-12. Trends in Kidney Cancer in Women (1995-2015)

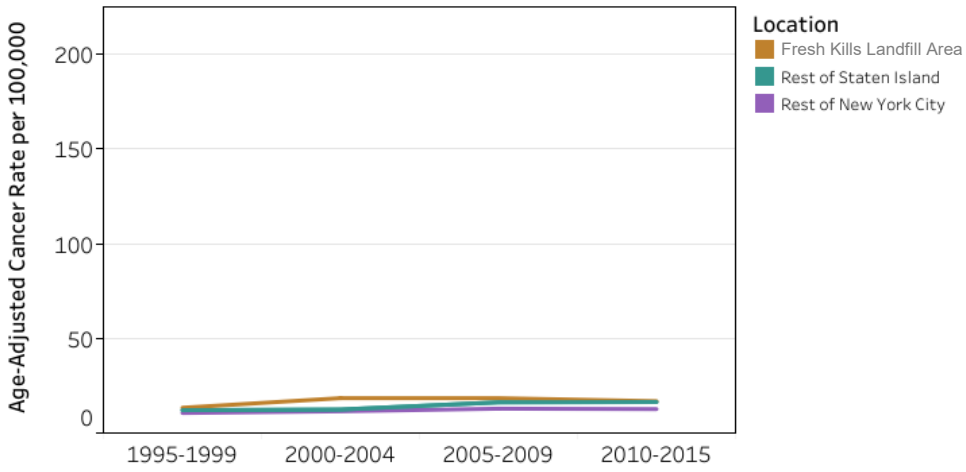
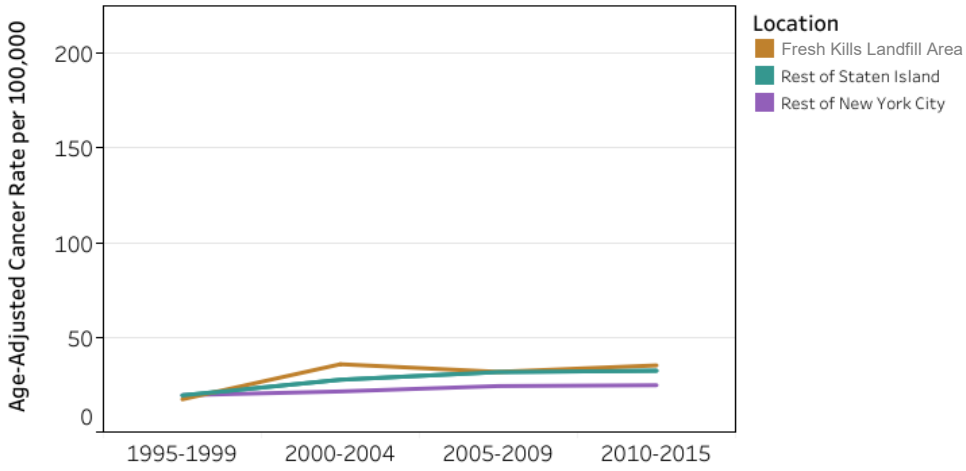


Figure III-13. Trends in Kidney Cancer in Men (1995-2015)



Known risk factors for kidney cancer include cigarette smoking; obesity; workplace exposure to cadmium (a metal), some herbicides and organic solvents, especially trichloroethylene; family history of kidney cancer; advanced kidney disease; and various inherited genes. Having high blood pressure and use of certain medications (*e.g.,* diuretics, phenacetin) may also increase the risk of developing kidney cancer. Black and Native American populations have slightly higher rates of kidney cancer than White populations, but the reasons for this are unclear. We were unable to control for any of these factors in our analyses, and the importance of cigarette smoking and its high prevalence in Staten Island was discussed above in relation to bladder cancer.

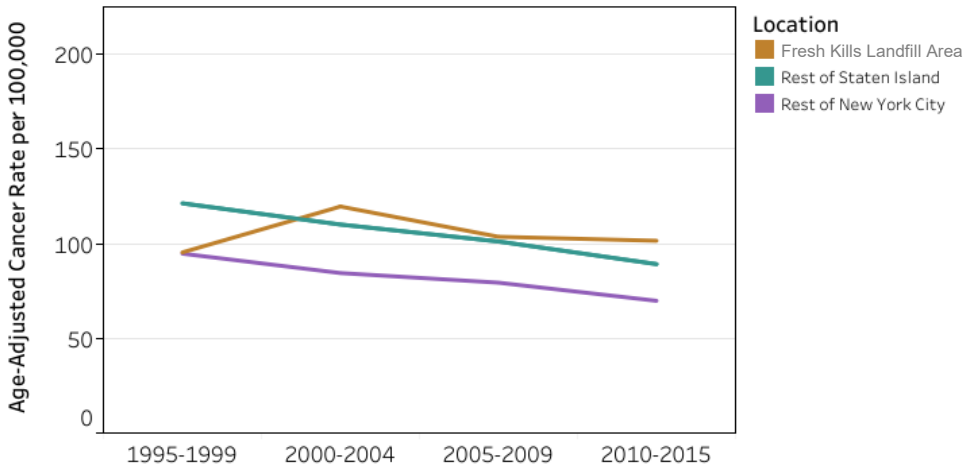
We found no consistent patterns of elevated kidney cancer rates in the former Fresh Kills Landfill study area. Results from the proximity analysis did not suggest that kidney cancer rates were higher near the landfill. The two previous NYC Health Department studies reported a

moderate non-significant elevation in men only, whereas the suggestive evidence in the current study was only among women.

4. Lung Cancer

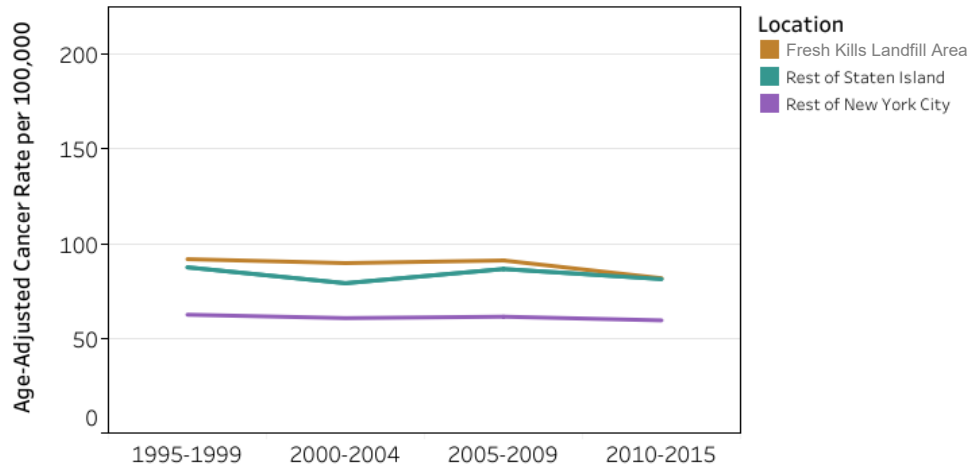
Lung cancer is the second most common cancer in men and women (after skin cancer) and the leading cause of cancer death in the U.S., NYS, and NYC.[27,28,29] Lung cancer rates on Staten Island are around 30% higher than the rest of NYC, but we did not find slight or moderate elevations in the former Fresh Kills Landfill area relative to the rest of Staten Island for 1995-2015 overall. However, we did find slightly elevated rates during some periods, which differed for men and women (Figure III-14 and Figure III-15).

Figure III-14. Trends in Lung Cancer in Men (1995-2015)



[27] American Cancer Society. (2019). Facts & Figures 2019: US Cancer Death Rate has Dropped 27% in 25 Years. Available at: https://www.cancer.org/latest-news/facts-and-figures-2019.html.
[28] American Cancer Society Cancer Action Center. (2019). Reducing the Cancer Burden in New York City. Available at: https://www.fightcancer.org/reducing-cancer-burden-new-york-city.
[29] New York State Health Department (NYSDH). 2018. Snapshot of Cancer in New York. Available at: https://www.health.ny.gov/statistics/cancer/registry/pdf/snapshot.pdf.

Figure III-15. Trends in Lung Cancer in Women (1995-2015)



Smoking is by far the leading risk factor for most forms of lung cancer (see discussion of higher rates of smoking in Staten Island in section on bladder cancer). Secondhand smoke also increases risk. Other environmental risk factors in the U.S. include exposure to radon and asbestos. Workplace risk factors include exposure to radioactive ores, inhaled arsenic and other elements, other chemicals, and diesel exhaust. Also, radiation to the chest, air pollution and family history have been shown to increase risk.

Because smoking rates are high in Staten Island compared with the rest of NYC and smoking is the most important risk factor for lung cancer, it is likely that lung cancer patterns in Staten Island are influenced by smoking patterns. As mentioned previously, we were not able to control for smoking in this (or earlier) studies, so we cannot rule it out as an explanation for the patterns we observed.

Lung cancer was not elevated overall in the analysis of the former Fresh Kills Landfill Study area compared with the rest of Staten Island, but we assessed it in the proximity analysis because of suggestive evidence from the previous NYC Health Department studies. Results from the proximity analysis corroborated initial findings that lung cancer rates were not higher near the landfill. The previous NYC Health Department studies found elevated rates only when comparing residents of the Fresh Kills Landfill area with those in the comparison neighborhoods outside of Staten Island – not with residents in the rest of Staten Island.

5. Non-Hodgkin Lymphoma

Non-Hodgkin lymphoma is a group of cancers that affect the lymphatic system and are more common in men than women. The risk of developing lymphoma generally increases with age and non-Hodgkin lymphoma affects White Americans more often than Asian or Black Americans. Non-Hodgkin lymphoma rates in 1995-2015 were slightly but inconsistently elevated among men and women living in Staten Island compared with the rest of NYC, across the four time periods (Figure III-16 and Figure III-17).

Among residents living in the former Fresh Kills Landfill study area, non-Hodgkin lymphoma rates in men were elevated compared with the rest of Staten Island during 2000-2009, while women had elevated rates during 1995-1999 and 2010-2015. The proximity analysis did not suggest that rates of non-Hodgkin lymphoma were higher nearer to the landfill in 1995-2004 or 2005-2015.

Figure III-16. Trends in Non-Hodgkin Lymphoma in Men (1995-2015)

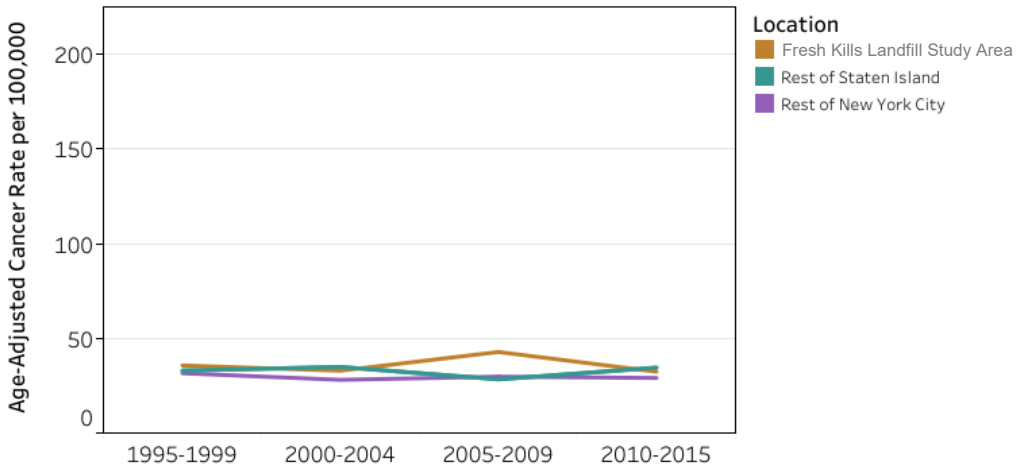
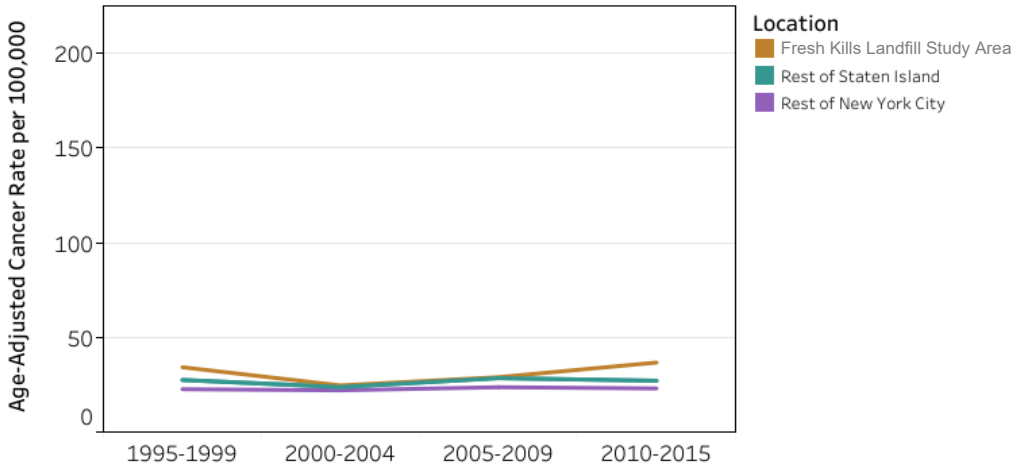


Figure III-17. Trends in Non-Hodgkin Lymphoma in Women (1995-2015)



In addition to age, sex, and race/ethnicity, known risk factors for Non-Hodgkin lymphoma include family history of Non-Hodgkin lymphoma; radiation exposure; and having a weakened immune system related to disease, treatment or genetics. Exposure to some commonly occurring chemicals, such as benzene and some herbicides and insecticides; certain drugs; and having certain autoimmune diseases, such as rheumatoid arthritis, have also been linked to an increased risk of Non-Hodgkin lymphoma. Infection with some viruses and bacteria may also elevate the risk of certain types of Non-Hodgkin lymphoma. Some studies, but not all, have linked Non-

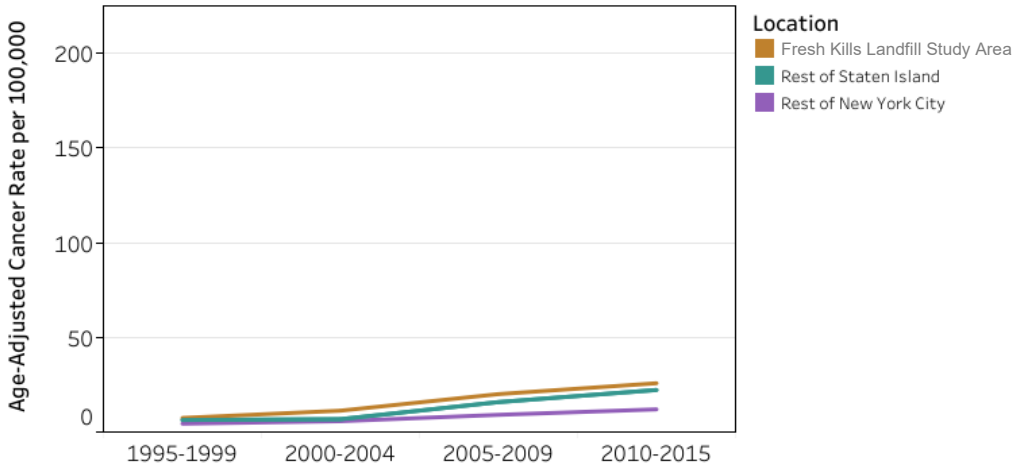
Hodgkin lymphoma to being overweight or obese, consuming a diet high in fat and meats, and certain types of breast implants.

6. Thyroid Cancer

Thyroid cancer is a relatively uncommon cancer, but since the 1990s, diagnosis of thyroid cancer has nearly tripled in both men and women in NYC and elsewhere.[30] The primary reason for the overall increase is thought to be expanded use of diagnostic procedures – in other words, physicians are now better at finding thyroid cancer than before. However, the U.S. Preventive Services Task Force recommends against screening for thyroid cancer in adults without any symptoms.[31] Most (approximately 90%) of the thyroid cancers detected are papillary carcinomas, which are slow-growing and rarely fatal. Mortality for thyroid cancer on Staten Island is extremely low and has mostly held steady over the past 10 years.[32]

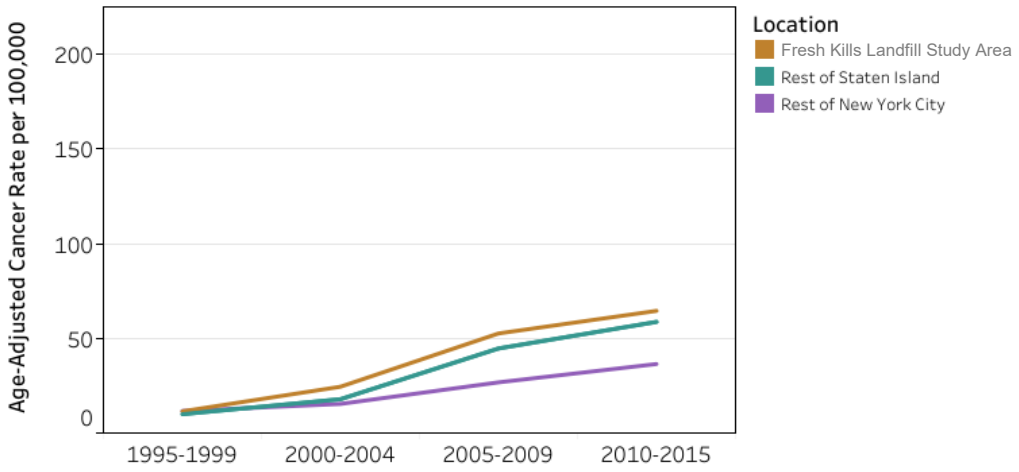
Over the 21-year period in this study, thyroid cancer rates were elevated for both men (Figure III-18) and women (Figure III-19) living in Staten Island compared with the rest of NYC. Among both men and women living in the former Freshkills Landfill study area, rates were moderately elevated compared with those for the rest of Staten Island.

Figure III-18. Trends in Thyroid Cancer in Men (1995-2015)



[30] American Cancer Society. 2019. Key Statistics for Thyroid Cancer. Available at: https://www.cancer.org/cancer/thyroid-cancer/about/key-statistics.html
[31] US Preventive Services Task Force. 2017. Screening for thryroid cancer: US Preventive Services Task Force Recommendation Statement. JAMA, 317(18): 1882-1887.
[32] American Cancer Society. 2019. Cancer Facts and Figures 2019. Available at: https://www.cancer.org/content/dam/cancer-org/research/cancer-facts-and-statistics/annual-cancer-facts-and-figures/2019/cancer-facts-and-figures-2019.pdf

Figure III-19. Trends in Thyroid Cancer in Women (1995-2015)



The elevation in the thyroid cancer rate in the former Fresh Kills Landfill study area relative to the rest of Staten Island peaked during 2000-2004 among both men and women, which was during and in the aftermath of the September 11, 2001 WTC attack. This was a period of heightened concern about exposure to chemicals and contaminants that might increase risk of cancers – exacerbated by the temporary use of the Fresh Kills Landfill to dispose of WTC debris. Combined with pre-existing concerns about cancer risks associated with living near the landfill, increased screening for thyroid cancer in the population living closest to the landfill could be one explanation for increased thyroid cancer diagnoses in this area.

Known risk factors for thyroid cancer are radiation exposure, a diet low in iodine, and certain genetic and hereditary conditions. It is very unlikely that there is an unrecognized radiation source in the former Fresh Kills Landfill study area.

Results from the proximity analysis suggest that thyroid cancer rates were higher near the landfill during the later period but not during 1995-2004. The analysis estimated that the number of thyroid cases that could have plausibly been associated with living near the former landfill in 2005-2015 ranged from one fewer to 16 additional cases each year. On average, there were an estimated seven excess cases each year. This association in the later period of our study coincides with a time when screening rates were also rising among Staten Island residents. With increased screening, we would expect to see increases in thyroid cancer diagnoses.

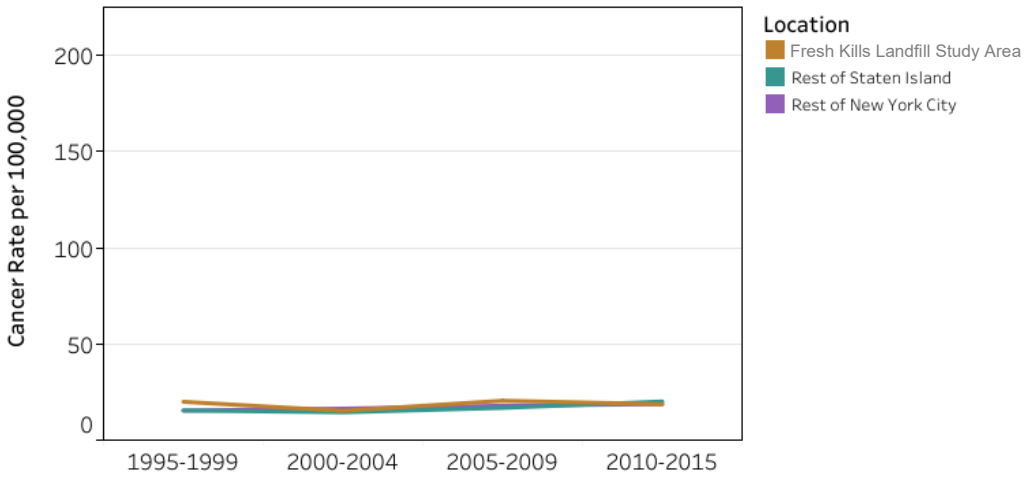
7. Total Childhood Cancer

Cancers in children and adolescents are different from those of adults both in the types of disease and how they are treated. Between 2011 and 2015, the most common types of cancer in children (0 to 14 years) and adolescents (15 to 19 years) in NYC were leukemia, brain and nervous system tumors, and lymphomas.[33] Within Staten Island, the neighborhood encompassing the

[33] New York State Cancer Registry. Childhood Cancer Incidence, New York City, 2011-2015. Cancer Incidence and Mortality in New York State, 1976-2015. Available at: http://www.health.ny.gov/statistics/cancer/registry/.

former Fresh Kills Landfill area had a rate of 247.0 childhood cancers per 1,000,000 children, compared with 255.7 per 1,000,000 children in Tottenville-Great Kills-Annadale, which is farther from the former landfill site and had the highest rate in the borough. The rates of total cancers among children were similar in the former Fresh Kills Landfill study area, the rest of Staten Island, and the rest of NYC (Figure III-20).

Figure III-20. Trends in Total Childhood Cancer (1995-2015)



Unlike for cancers in adults, there are few known risk factors for childhood cancers. Genetic mutations passed from parent to child or that develop while the fetus is in the womb cause about 10% of all childhood cancers. Less than 5 to 10% of childhood cancers worldwide have known environmental causes. Exposure to ionizing radiation after atomic bomb attacks at Hiroshima and Nagasaki is an example of an environmental disaster that increased risk of childhood leukemia.[34] Although risk factors for childhood cancer are an active area of research, we do not know what causes more than 80% of these cancers.

Results from the proximity analysis did not suggest that childhood cancer rates were higher near the landfill, mirroring the lack of association in the comparison of the former Fresh Kills Landfill study area to the rest of Staten Island and the findings from the previous NYC Health Department studies.

B. Asthma

Asthma is a chronic lung disease that makes it difficult to move air in and out of the lungs. Asthma can begin at any age and only one of two types of occupational asthma is associated with a latency period.[35] Risk factors for the development and exacerbation of asthma include a family

[34] Preston, D.L., Kusumi, S., et al. 1994. Cancer incidence in atomic-bomb survivors. Part III: Leukemia, lymphoma, and multiple myeloma, 1950-1987. Radiation Research, 137: S68-97.
[35] Christiani, D.C. 2010. Update on Occupational Asthma. Available at: http://www.asthma.partners.org/NewFiles/ChristianiOccupationalAsthma.html.

history, allergies, respiratory infections, and obesity. Environmental risk factors such as tobacco smoke, pollen, air pollution, and indoor allergens from mice, cockroaches and mold also can play a critical role in the development and exacerbation of asthma symptoms in adults and children. All of these risk factors are important to consider while evaluating the burden of asthma in a community.[36] For adults, occupational exposures may also cause or trigger asthma.

Measuring current asthma prevalence in adults and children on a community level can be difficult because health care providers are not required to report asthma diagnoses to local, state or federal health agencies – as they are for cancer. Asthma morbidity is usually assessed by examining rates of asthma-related emergency department visits and hospitalizations. These measures reflect use of the health care system for treating asthma, but do not necessarily reflect the true burden of disease in a community. Information not captured by asthma-related health care utilization measures include overall incidence (new cases) and prevalence (total number of people living with asthma). Additionally, there are many types of asthma experienced in adults and children with varying causes and triggers.

Examples of environmental risk factors and triggers originating from the former Fresh Kills Landfill may have included particulates from municipal waste, chemicals, or other operations on the landfill site. Now that the landfill is closed and mostly capped, asthma triggers from the Freshkills Park would be similar to other parks, including pollen from trees and fungal spores. We further investigated death due to chronic respiratory disease to address the limitations of data on health care use (Section III-C).

Using available data, we evaluated rates of asthma-related emergency department visits and hospitalizations by borough in NYC and on a neighborhood level in Staten Island. An overview of the available data, neighborhood definitions, the methods used for evaluating asthma in the areas of interest, and all associated results can be found in Appendix H.

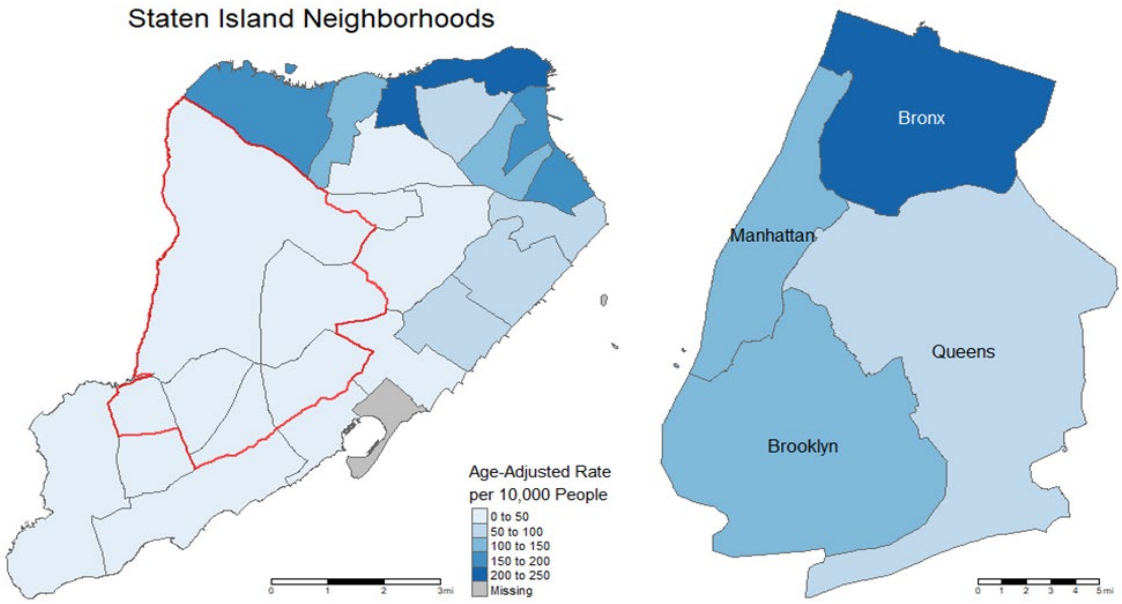
Rates of asthma-related emergency department visits and hospitalizations for adults and children were lower in Staten Island compared with NYC overall (Figure III-22). Within Staten Island, the six neighborhoods intersecting the former Fresh Kills Landfill study area had lower rates of asthma-related emergency department visits for adults and children compared with Staten Island neighborhoods outside the former Fresh Kills Landfill study area. The pattern was similar when comparing asthma-related hospitalization rates for these same areas. Asthma-related emergency department visits and hospitalizations were highest in Staten Island for the northernmost neighborhoods including Mariner's Harbor-Arlington-Port Ivory-Graniteville, Port Richmond, Stapleton-Rosebank, and West New Brighton-New Brighton-St. George. Rates in these neighborhoods were higher than both Staten Island and NYC overall.

Staten Island had lower rates of asthma-related emergency department visit among adults compared with NYC overall for 2012-2014 (Figure III-21). Focusing on the six NTAs that

[36] American Lung Association. 2018. Asthma Risk Factors. Available at: https://www.lung.org/lung-health-and-diseases/lung-disease-lookup/asthma/asthma-symptoms-causes-risk-factors/asthma-risk-factors.html

overlap with the former landfill site, rates of asthma-related emergency department visits were lower than in the rest of Staten Island overall as well.

Figure III-21. Age-Adjusted Rates of Asthma-related Emergency Department Visits among Adults in Staten Island Neighborhoods and other New York City Boroughs, 2012-2014



Neighborhood is defined as a Neighborhood Tabulation Area. Red outline indicates the former Fresh Kills Landfill study area.

When examining asthma-related hospitalization rates among adults, we again found lower rates in the neighborhoods near the landfill and in the rest of Staten Island compared with the rest of NYC. In children in the former Fresh Kills Landfill study area and in the rest of Staten Island, asthma-related hospitalizations and emergency department visits also were lower than among children in the rest of NYC (Appendix H).

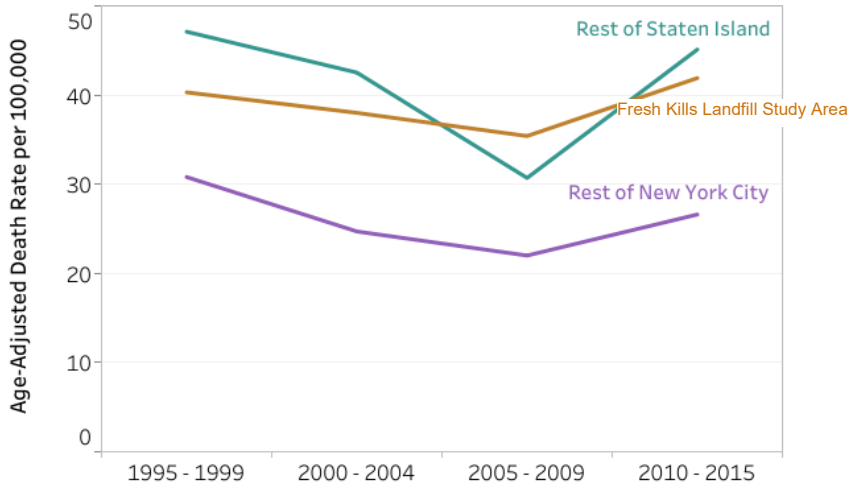
C. Causes of Death

This study examined deaths due to causes other than injury (such as car crashes, suicides, poisonings, *etc.*). Death rates were generally lower in the rest of NYC than in the former Fresh Kills Landfill study area and the rest of Staten Island. Death rates decreased in all three geographic areas from 1995 to 2015 among men, while among women, rates increased in the Fresh Kills Landfill study area compared with little overall change in the rest of Staten Island and slight declines in the rest of New York City. Among both men and women, age-adjusted death rates were lower in the former Fresh Kills Landfill study area relative to the rest of Staten Island in 1995-2004, while they were slightly elevated in 2005-2015. The highest MRRs (1.10 for men and 1.15 for women) were observed in 2005-2010. For detailed results, please see Appendix G.

We also looked at death rates specifically from chronic lower respiratory disease, a group of illnesses that obstruct the lungs, such as chronic obstructive pulmonary disease (COPD) and asthma. In 2015, 6.7% of all deaths in the U.S. were due to chronic respiratory diseases, the fifth leading cause of death.[37] Chronic respiratory disease death was selected for study by the SAC to address community concerns about health risks related to airborne exposures from the former landfill.

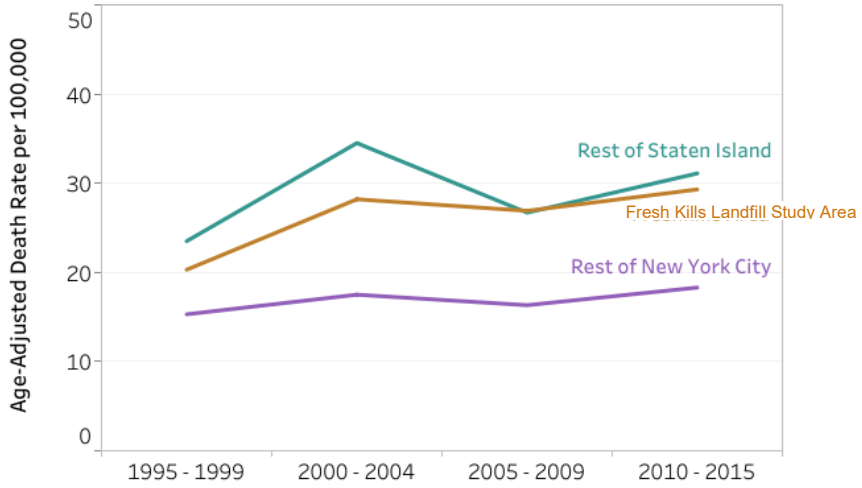
In the former Fresh Kills Landfill study area, a total of 432 per 100,000 deaths due to chronic lower respiratory diseases were reported between 1995 and 2015. For both men and women, the age-adjusted chronic lower respiratory death rates were generally lower in the former Fresh Kills Landfill study area than the rest of Staten Island, but higher than in the rest of NYC (Figure III-22 and Figure III-23). From 1995 to 2015, the death rates due to chronic lower respiratory diseases increased slightly across all three geographic areas for women, but only slightly in the former Fresh Kills Landfill study area for men.

Figure III-22. Trends in Mortality Due to Chronic Lower Respiratory Diseases in Men (1995-2015)



[37] Dwyer-Lindgren, L., Bertozzi-Villa, A., Stubbs, R.W. et al. 2017. Trends and Patterns of Differences in Chronic Respiratory Disease Mortality Among US Counties, 1980-2014. JAMA, 318(12):1136-1149.

Figure III-23. Trends in Mortality Due to Chronic Lower Respiratory Diseases in Women (1995-2015)



Like cancer, chronic diseases of the lower respiratory tract typically develop over a long time period. For example, most people are at least 40 years old when COPD symptoms begin, and both illness and death are more common in the elderly.[38] Tobacco smoking increases risk of the development and progression of chronic respiratory diseases, although exposure to air pollutants in the home and workplace, genetic factors, and respiratory infections also play a role. Since available data were based on where residents lived at the time of death, residential mobility remains an important issue to consider when reviewing these results. In the former Fresh Kills Landfill study area compared to the rest of Staten Island, we did not observe elevations in the age-adjusted death rate ratios for either women or men during any period from 1995-2015.

IV. Conclusions

The NYC Health Department conducted this *Descriptive Study of Cancer, Asthma and Other Health Outcomes Around the former Fresh Kills Landfill, Staten Island* to continue analyses begun in the 1996 Staten Island Cancer Incidence Study and its 2000 addendum. The previous and current studies describe patterns of new cancer cases in Staten Island based on how close residents lived to the site of the former Fresh Kills Landfill. The current study also examined asthma health care use and death (excluding injury) with a focus on chronic lower respiratory disease. We drew conclusions based on the patterns we observed in the rates of health outcomes – especially during earlier years when the landfill had already been operating for over 40 years and was not yet closed; available information on risk factors; and evidence on exposure pathways from the Fresh Kills Landfill.

[38] Buist, S., McBurnie, M.A., Vollmer, W.M., et al. 2007. International variation in the prevalence of COPD (the BOLD study): a population-based prevalence study. Lancet, 370: 741-750.

While this and the two previous studies were designed to describe patterns that could suggest a connection between living close to the landfill and health, we could not evaluate what caused new cancer cases, asthma (new cases or exacerbations) or deaths not due to injury. However, we did evaluate the evidence for elevations in the former Fresh Kills Landfill study area. If exposures from the former Fresh Kills Landfill increased cancer risk in nearby communities, we would expect to see consistent patterns in both types and rates of cancers across the three studies and over time, as well as similar increases or decreases in both men and women.

We compared rates of 17 cancer types in the former Fresh Kills Landfill study area with rates in the rest of Staten Island in 1995-2015. We found slight or moderate elevations in the former Fresh Kills Landfill study area for five cancer types: bladder, breast (women only), non-Hodgkin lymphoma, kidney, and thyroid. Within each cancer type, the trends did not show a consistent increase over time or between men and women. We conducted a more rigorous examination of patterns by proximity to the former landfill area for these five cancer types in two periods: 1995-2004 and 2005-2015. We found that none of these five cancers were elevated throughout the entire study period. The only evidence for elevation in rates nearer the former landfill site was for thyroid and bladder cancer in 2005-2015.

Although we found higher rates in these two cancers in the former Fresh Kills Landfill study area, we were unable to find evidence to support a link to potential landfill-related exposures. Variation in known risk factors and cancer detection rates across Staten Island are plausible explanations for the patterns we observed, but it was not possible to control for these sources of bias in this descriptive study. For example, screening for thyroid cancer increased rapidly during the timeframe for this study, and more screening in the former Fresh Kills Landfill study area than in other parts of Staten Island is one possible explanation for higher thyroid cancer rates. Similarly, we were unable to control for differences in smoking, which is an important risk factor for bladder cancer.

Asthma-related health care use – visits to the emergency department and hospital stays – were consistently lower in the communities near the former landfill compared with other parts of Staten Island. Our examination of deaths not due to injury found a slight elevation in the former Fresh Kills Landfill study area rates in 2010-2015, but there were no elevations in chronic lower respiratory disease death rates among men or women during the study period.

After reviewing the scientific evidence and conducting three descriptive studies of health outcomes on Staten Island, we do not have evidence to conclude that exposures from the former Fresh Kills Landfill caused cancer, asthma, or death in the surrounding residential community.

V. Appendices

Appendix A. Scientific Advisory Committee Members

Name	Affiliation
Nicole Bock	Northwell Health
Joe Borelli	New York City Council, District 51
Caitlin Field	Freshkills Park, NYC Department of Parks and Recreation
Donna Gerstle	College of Staten Island/CUNY
Cliff Hagen	President, Protectors of Pine Oak Woods; Special education teacher
Julie Herbstman	Columbia University
Nisha Lakhi	New York Medical College, Richmond University Medical Center of Staten Island
Laura Longo	Northwell Health
Ginny Mantello	Staten Island Borough President's Office
Frank Mascia	New York City Council, District 51
Wendy Mckelvey	New York City Department of Health and Mental Hygiene
Terenig Terjanian	Northwell Health
Laura Truettner	Freshkills Park, NYC Department of Parks and Recreation
Jermain Williams	New York City Department of Health and Mental Hygiene
Ricky Wong	New York City Department of Health and Mental Hygiene

Appendix B. List of Census Tracts

Fresh Kills Landfill Study area

The former Fresh Kills Landfill study area was comprised of the following 2010 U.S. Census Tracts surrounding the former Fresh Kills and Brookfield Avenue landfills:

146.04, 146.05, 146.06, 146.07, 146.08, 170.05, 170.07, 170.08, 170.09, 170.10, 170.11, 170.12, 208.01, 228*, 273.01, 273.02, 277.02, 277.04, 277.05, 277.06, 279, 291.02, 291.03, 291.04

*Tract 228 contains the former Fresh Kills Landfill/Freshkills Park and was excluded from the cancer proximity analyses, because population was either zero or very small during the study period.

Borough of Staten Island (Richmond County) Overall

The 2010 U.S. Census Tracts for Richmond County can be found at https://labor.ny.gov/nys-data-center/2010-Census-Tract-Maps/RichmondCT.pdf and include:

3, 6, 7, 8, 9, 11, 17, 18, 20.01, 20.02, 21, 27, 29, 33, 36, 39, 40, 47, 50, 59, 64, 67, 70, 74, 75, 77, 81, 96.01, 96.02, 97, 105, 112.01, 112.02, 114.01, 114.02, 121, 122, 125, 128.04, 128.05, 128.06, 132.01, 132.03, 132.04, 133.01, 133.02, 134, 138, 141, 146.04, 146.05, 146.06, 146.07, 146.08, 147, 151, 156.01, 156.02, 156.03, 169.01, 170.05, 170.07, 170.08, 170.09, 170.1, 170.11, 170.12, 173, 176, 177, 181, 187.01, 187.02, 189.01, 189.02, 197, 198, 201, 207, 208.01, 208.03, 208.04, 213, 223, 226, 231, 239, 244.01, 244.02, 247, 248, 251, 273.01, 273.02, 277.02, 277.04, 277.05, 277.06, 279, 291.02, 228, 291.03, 291.04, 303.01, 303.02, 319.01, 319.02, 323

The Rest of Staten Island (excluding the Fresh Kills Landfill area)

The rest of Staten Island was defined as the borough of Staten Island (Richmond County) minus the former Fresh Kills Landfill study area census tracts. The following census tracts make up "the rest of Staten Island":

3, 6, 7, 8, 9, 11, 17, 18, 20.01, 20.02, 21, 27, 29, 33, 36, 39, 40, 47, 50, 59, 64, 67, 70, 74, 75, 77, 81, 96.01, 96.02, 97, 105, 112.01, 112.02, 114.01, 114.02, 121, 122, 125, 128.04, 128.05, 128.06, 132.01, 132.03, 132.04, 133.01, 133.02, 134, 138, 141, 147, 151, 156.01, 156.02, 156.03, 169.01, 173, 176, 177, 181, 187.01, 187.02, 189.01, 189.02, 197, 198, 201, 207, 208.03, 208.04, 213, 223, 226, 231, 239, 244.01, 244.02, 247, 248, 251, 273.01, 303.01, 303.02, 319.01, 319.02, 323

Rest of New York City

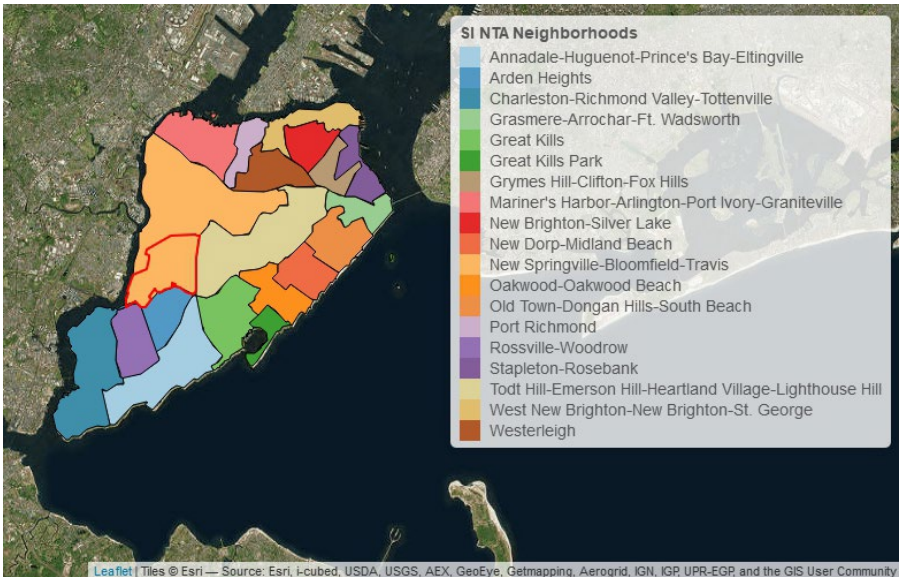
The rest of New York City was defined as New York City minus the borough of Staten Island.

Appendix C. Maps of the Areas of Interest for this Study

This section provides various maps of the former Fresh Kills Landfill study area, Staten Island, and other areas of interest in this study.

The map in Figure C-1 illustrates Staten Island's 18 Neighborhood Tabulation Areas (NTAs). Six of these NTAs intersect the former Fresh Kills Landfill study area: Annandale-Huguenot-Prince's Bay-Eltingville, Arden Heights, Great Kills, New Springville-Bloomfield Travis, Rossville-Woodrow, and Todt Hill-Emerson Hill-Heartland Village-Lighthouse Hill.

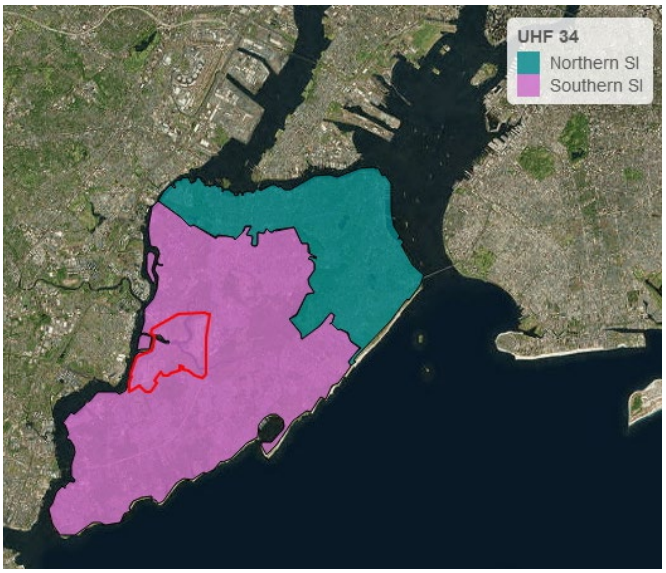
Figure C-1. Staten Island Neighborhood Tabulation Areas (NTAs)



Red outline indicates the former Fresh Kills Landfill site

The map in Figure C-2 depicts the two United Hospital Fund (UHF 34) neighborhoods in Staten Island. There are two UHF neighborhoods: Northern Staten Island (UHF 501/502) and Southern Staten Island (503/504). The former Fresh Kills Landfill study area overlaps with Southern Staten Island (UHF 503/504). Data on the prevalence of various risk factors of interest in this study (see Appendix I, Table I-2) were collected at the UHF 34 neighborhood level.

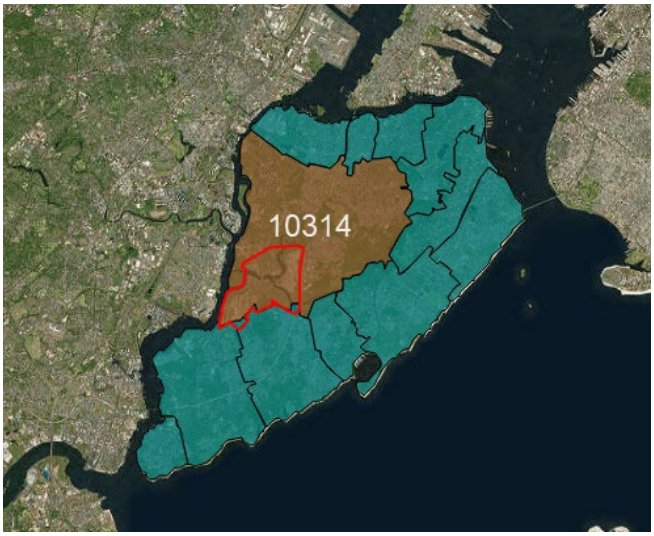
Figure C-2. Staten Island United Hospital Fund Neighborhoods in Staten Island



Red outline indicates the former Fresh Kills Landfill site

The map in Figure C-3 depicts the areas of Staten Island that correspond with various ZIP Codes. The zip code 10314 encompasses the former Fresh Kills Landfill study area and also includes some neighboring communities. Data on the prevalence of various demographic factors of interest in this study (see Appendix I, Table I-2) were collected at the zip code level. Note that the area outlined in red represents the former Fresh Kills Landfill.

Figure C-3. Staten Island Zip Codes



Red outline indicates the former Fresh Kills Landfill site

Appendix D. Analysis Methods

This section provides details on the statistical analyses used in this study.

D-1. Calculation of Incidence Rates and Standardized Incidence Ratios or Mortality Rate Ratios

We calculated both annual crude and age-adjusted, sex-specific incidence rates and standardized incidence ratios (SIRs) for cancer for the former Fresh Kills Landfill study area, the rest of Staten Island, and the rest of New York City for 1995-2015 overall and also for four periods (1995 to 1999, 2000 to 2004, 2005 to 2009, and 2010 to 2015). Cancer incidence rates are calculated by dividing the number of people who developed cancer (the numerator) by the total number of people in the population (the denominator) for a given timeframe.

For cancer incidence numerators, we obtained data on cancer cases from the NYS Health Department Cancer Registry grouped by site of cancer.

For cancer incidence denominators, we used single-year population estimates by age and sex for census tracts in New York State from the New York State Department of Health Cancer Registry (communication from Francis Boscoe). Briefly, these population estimates were calculated using iterative proportional fitting to develop populations that are consistent with Census Bureau tract-level populations from 1990, 2000, and 2010, and single-year county-level population estimates published by the Surveillance, Epidemiology, and End Results (SEER) Program of the National Cancer Institute (https://seer.cancer.gov/popdata/). The Longitudinal Tract Database (LTDB) (https://s4.ad.brown.edu/projects/diversity/researcher/bridging.htm) was used to report populations using 2010 census tract boundaries. This approach assumes that population growth or reduction at the tract level reflects what is happening at the county level and is an improvement over linear or geometric interpolation between census years.

Crude cancer rates by period and overall were calculated separately for children (≤14 years old), men, and women by dividing the annual number of new cancer cases by group in an area (numerator) by the population of the group in the same area (denominator). For adults, we also calculated age-adjusted rates using a standard population calculated by summing the New York State population over the entire study period (1995-2015) for each age group and sex. Because of the small number of cases, child rates were not age-adjusted. Age-adjusted overall cancer rates were also adjusted for year of diagnosis.

Age-adjusted mortality rates were calculated by the NYC Health Department Office of Vital Statistics for adults ages 15 years and older using Census 2000 population by census tract from Table PCT012 Sex by Age Census 2000 Summary File 1 (SF 1) 100-percent as denominator and the 2000 U.S. projected population and age-adjustment weights from “Healthy People 2010 Statistical Notes No. 20, Jan 2001”.

The cancer SIR is the number of observed cancer cases divided by the number of cases we would expect in an area if it had experienced the same rates as the comparison area. The mortality rate ratio (MRR) is an area's death rate divided by the death rate in the comparison area, both age-adjusted in this study. Assessment of elevation for each SIR or MRR was made based on magnitude and *p*-value. Since the SIR is a ratio, a value of 1.0 signifies that the number of observed cases is the same as the number of expected cases, given the population and age distribution for that community. Similarly, an MRR of 1.0 indicates the same death rate in the area of interest and the comparison area. The *p*-value is used to determine how likely an observed deviation from 1.0 would be if the true value is 1.0. The *p*-value takes into account random variation that is always present when estimating rate across time and place. If the *p*-value is greater than or equal to 0.05, then we do not consider the SIR (MRR) to be statistically significantly different from 1.0. We further defined SIRs (MRRs) of 1.06 to 1.24 as slightly elevated and SIRs greater than 1.24 as moderately elevated; an SIR or MRR less than 1.06 was not considered elevated.

Cancer rates are provided in Appendix E and mortality rates are in Appendix G.

D-2. Trend Analysis for the Years 1995–2015

Trend analyses were used to determine how incidence rates for health outcomes of interest changed over the 21-year time period (1990-2015). For the study and comparison areas, annual age-adjusted incidence rates were calculated for the four periods from 1995 to 2015 (1995 to 1999, 2000 to 2004, 2005 to 2009, and 2010 to 2015) for men and women. Given the small number of cases and limited age range, for children we used crude incidence rates.

Regression analysis was used to determine whether there was a statistically significant ($p<0.05$) increasing or decreasing trend in the cancer incidence rates in the former Fresh Kills Landfill study area, the rest of Staten Island, and the rest of New York City.

Rates of cancers fluctuate from year to year. In a specific geographic area, they might be higher in one year and lower in the next year. These differences do not necessarily indicate that there has been a meaningful change in rates. When the rates are plotted on a graph, they are generally scattered and do not fall on a straight line. However, a regression line may show an overall increase or decrease in rates over time. We regressed the age-adjusted incidence rates against the midpoint of each of the four time periods. The regression coefficient of the midpoint variable represents the steepness of the slope of this straight line. For the trend analyses a positive coefficient indicates that the incidence rates were increasing over time. A negative coefficient represents a decrease in rates over time (although the rates may have varied slightly up or down from year to year). For example, a coefficient of 1.8 means that for every period, on average, the incidence rate increased by 1.8 cases/100,000 people. The larger the magnitude of the coefficient, the steeper the slope of the line. A coefficient equal to or close to zero means that the trend was neither increasing nor decreasing. The significance of the slope coefficient is evaluated using the Wald *p*-value with a significance level of alpha=0.05. Thus, a *p*-value less than 0.05 ($p<0.05$) indicates statistically significant increase or decrease in rates over time

D-3. Bayesian Modeling of Proximity and Risk

To enhance this analysis and go beyond the ecological comparison approach used in the previous NYC Health Department *Staten Island Cancer Incidence Study* and its addendum, we evaluated the ***risk of cancer in relation to proximity*** to the former Fresh Kills landfill. Application of this method to address public health-based questions has grown since the NYC Health Department's most recent study in 2000. Seven specific cancers were modeled using the Bayesian approach described by Wakefield and Morris.[39] The following criteria were used to select these specific cancers:

- Specific cancers with a SIR greater than 1.05 for both men and women for the former Freshkills Landfill study area versus the rest of Staten Island. Consistent with previous studies, SIR greater than 1.05 was defined as the criterion for a slight elevation.
- For those specific cancer types meeting the first criteria, the "all years" *p*-value less than 0.10 for both men and women.
- Inclusion of additional cancers because of community interest or identified as elevated in previous studies of the Fresh Kills Landfill area (*e.g.*, the Governor's Initiative, the previous NYC Health Department studies).

Bladder, kidney, and thyroid cancer and Non-Hodgkin lymphoma in men and women had overall SIR values greater than 1.05 as did myeloma in men and leukemia and breast cancer in women. With the exception of myeloma in men and leukemia in women, the SIRs for these specific cancers also had a *p*-value less than or equal to 0.10. Lung cancer for both men and women and total cancer for children were included because they were identified in the previous NYC Health Department Study and its addendum as elevated or of interest to the Freshkills area community.

D-3.1 Tract SIR and Z

For each of the 107 tracts in Staten Island, we calculated census tract SIRs for each cancer site selected for Bayesian analysis over two periods (1995-2004 and 2005-2015). The tract SIR estimates the relative cancer risk in a census tract compared with the rest of New York City (excluding Staten Island), adjusting for age, sex and year of diagnosis.

The tract SIR is defined by the equation:

$$\text{Tract SIR} = \frac{\text{Observed cancer cases}}{\text{Expected cancer cases}} = \frac{\text{Observed cancer cases}}{\sum \text{Number of persons in tract (year,age group,sex)} \times \text{Reference area cancer rate (year,age group,sex)}}$$

The observed cancer cases in the numerator is the number of cases from the census tract that were diagnosed during the period of interest. The sum in the denominator is the expected count across all combinations of year, five-year age group, and sex in the census tract. The reference

[39] Wakefield, J.C and Morris, S.E. 2001. The Bayesian modelling of disease risk in relation to a point source. Journal of American Statistical Association, 96 (435): 77-91.

area cancer rates by diagnosis year, age group, and sex are calculated from the data for the rest of New York City (excluding Staten Island) using the equation:

$$\text{Reference area cancer rates (year, age group, sex)} = \frac{\text{Cancer cases NYC} - \text{SI (year, age group, sex)}}{\text{Population NYC} - \text{SI (year, age group, sex)}}$$

We defined a measure of socioeconomic deprivation (Z) using household income data from the 1990 and 2000 census for years 1995 to 2002 and 2003 to 2011, respectively, and the 2006 to 2010 American Community Survey for years 2012 to 2015. We divided the tract median family income by the median family income for the Metropolitan area (× 100%). The percentage is subtracted from 100 so that tracts with a higher median income are assigned a low value of Z, and higher values represent higher deprivation. For the 1995-2004 period, when census tract income was not available from Census 1990 or 2000 (depending on the calendar year), the average of the income values available for the tract in other years from 1995 to 2004 was substituted. In the rarer cases of tracts where there were no data on census tract income, the average across all other tracts with data from Census 1990 or 2000 (depending on the calendar year) was substituted. A similar approach was used for 2005 to 2015, when census or American Community Survey tract income was not available from the census or American Community Survey.

D-3.2 Non-Parametric Model: Stone's Test

We used Stone's test to corroborate the presence of an association between proximity to the landfill and cancer risk that was suggested by apparent elevations from the initial SIR comparison. Stone's test is based on a non-parametric model that does not assume any specific shape of functions between cancer rates (as defined by the tract SIR) and the distance to the landfill centroid. The null hypotheses is that relative risks are constant across tracts, while the alternative is that there is a descending trend in relative risks as distance to the former landfill increases. Each cancer type and period (1995-2004 or 2005-2015) was analyzed separately. We numbered the tracts from 1 to 107 so that Tract 1 is the furthest from the landfill centroid, Tract 2 is the second furthest, and so on. Tract 107 is the closest to the landfill. Suppose O(i) is the observed number of cases in tract i and E(i) is the expected number of cases in tract i, defined in the previous subsection as the denominator of the tract SIR. The relative cancer risk for the tract is $\lambda(i)$. The observed number of cases, O(i), is assumed to have a Poisson distribution with a mean of $E(i) \times \lambda(i)$.

The null hypothesis is no landfill effect, which is interpreted as $\lambda(1) = \lambda(2) = \ldots = \lambda(107)$, so that the relative risk is the same for every tract. The alternative hypothesis is that the relative risk increases as you get closer to the landfill, so that $\lambda(1) \leq \lambda(2) \leq \ldots \leq \lambda(107)$. SAS statistical software was used to fit these two statistical models by the method of maximum likelihood. The test statistic is the standard likelihood ratio statistic LRT which is calculated as twice the difference between the log-likelihood for the alternative hypothesis and the log-likelihood for the null hypothesis. The *p*-value for this test was estimated by using the Monte Carlo method of

simulating data 1000 times under the null hypothesis assumption of no landfill effect and computing the distribution of LRT. This procedure is as described in Wakefield and Morris (2001, Section 3.1) and their references. P-values below 5% are evidence that the relative risk increases with proximity to the landfill, using a 5% significance level.

The results of Stone's test for each cancer site and time period can be found in Appendix F, Table F-1.

D-3.3 The Bayesian Model

The Bayesian approach begins with a statistical model for the cancer risk in each tract that includes some unknown parameters. The values of the unknown parameters are initially assumed to be drawn from specified statistical distributions that are called prior distributions. The modeled distribution of the observed data depends on the parameters. Given the observed data, the probability distributions of these parameters change, and the new distributions for the unknown parameters are called the posterior distributions. The Bayesian model adjusted for Z – our measure of socioeconomic status described above. Proximity to the landfill was calculated as the distance (in miles) between the tract centroid and the centroid of the Freshkills area. The Bayesian model was fitted using WinBUGS14 statistical software which calculates posterior distributions using a Markov Chain Monte Carlo (MCMC) simulation.

Following Wakefield and Morris, the observed count is assumed to have a Poisson distribution with a mean equal to the expected number of cases in the tract multiplied by the relative risk.[40] As explained above, the expected number of cases is the denominator of the tract SIR, and was calculated by applying the cancer rate in the NYC boroughs (minus Staten Island) by age, sex, and year to the tract population by age, sex, and year. The full model assumes that the relative risk of cancer increases with decreasing distance so that at distance d (miles) from the source (Fresh Kills centroid), the risk is multiplied by $f(d, \theta) = 1 + \alpha \exp(-(d/\beta)^2)$, which depends on the two parameters alpha (α) and beta (β) (see Wakefield and Morris, 2001). The model also includes parameters rho (ρ) (adjusting for the relative cancer rate in Staten Island *versus* the rest of New York City) non-spatial and spatial random effects V and U, and Z (census tract-level income as defined above). Expected counts are adjusted for age and sex

Mathematically, the model can be written as follows. Let i be the tract number. Y_i is the observed cases in tract i, which has a Poisson distribution. E_i is the expected cases in tract i. λ_i is the relative risk in tract i. Z_i is the socioeconomic deprivation for tract i. d_i is the distance between tract i and the Fresh Kills Landfill centroid. V_i is a random effect for tract i that is independent and identically normally distributed across the tracts. U_i is a random effect for tract i that is normally distributed and the correlation between different tracts is $\exp(-d\psi)$, where d is the distance between the two tracts.

[40] Wakefield, J.C and Morris, S.E. 2001. The Bayesian modelling of disease risk in relation to a point source. Journal of American Statistical Association, 96 (435): 77-91.

$$Y_i \sim \text{Poisson}(E_i \lambda_i), i = 1, \ldots, 107$$

$$\log(\lambda_i) = \log(\rho) + Z_i \phi + \log(1 + \alpha \exp[-(d_i/\beta)^2]) + V_i + U_i$$

$$V_i \sim N(0, \sigma_v^2)$$

$$U_i \sim (0, \sigma_u^2), \text{corr}(U_j, U_k) = \exp(-d_{jk} \psi)$$

The second equation shows how the relative risk depends on Z, V, U, and the unknown parameters. Note that this λ_i is not the same as the λ(i) used for Stone's test since Stone's test uses a non-parametric model for the relative risk. The parameters are α, β, ρ, ϕ, σ_v^2, σ_u^2, and ψ, which are all assigned prior distributions.

The most important parameters are α, β, and ρ. If the parameter α is positive, then the model predicts that the cancer risk is higher nearer the landfill. If the parameter α is negative, then the model predicts that the cancer risk is lower nearer the landfill. If the parameter α is zero, then the landfill has no predicted effect. For α, we also estimated the probability that α > 0, *i.e.*, Prob(α > 0), as the mean of the function equal to 1 when α > 0 and 0 otherwise. Prob(α > 0) is the predicted probability that the cancer risk is higher nearer the landfill. The parameter β is always positive. The size of β determines the rate at which the cancer risk increases or decreases with distance from the landfill. The parameter ρ represents the relative cancer risk between Staten Island and the rest of New York City. It can be initially estimated by the SIR for all of Staten Island versus the rest of New York City. This parameter is necessary because the expected cancer cases in the Staten Island tracts were based on the cancer rates in the rest of New York City.

This model is called the "proximity to landfill" model. It can be used to estimate the median number of cases in each tract together with a 95% credible interval, which is from the 2.5th percentile to the 97.5th percentile. If we use the same fitted model parameters but replace α by zero, then the new fitted model does not have a distance-risk function f(d, θ); we call this model the "landfill effect removed" model. The difference between the predicted cases from the two models estimates the number of cancer cases that could be attributable to the presence of the landfill in Staten Island.

In the Bayesian formulation of the model we assumed mostly uninformative priors for the distributions of the model parameters, based on the approach used by Wakefield and Morris (2001). By "uninformative", we mean that we did not make any assumptions about the presence or the absence of a "landfill effect". The prior distributions were chosen to avoid wildly unrealistic models.

The following prior distributions were used: For ρ, the maximum likelihood estimate under the null model without the income variable Z and random effects is the standardized incidence ratio, SIR, for all of Staten Island, which is the relative risk in Staten Island compared to the rest of New York City. The prior distribution for log(ρ) was chosen to be a normal distribution with a mean of zero and a standard deviation calculated to make the probability close to 90% that ρ is within a factor of three of the Staten Island SIR. The standard deviation varies for the different

combinations of demographic group, cancer site, and time period. The variance components for the random effects were chosen to have the uninformative priors of inverse gamma distributions Ga(0.5, 0.0005), as in Wakefield and Morris.[41] The correlation matrix for the spatial random effect U is of the form exp(−dψ), where d is the distance in miles between two tract centroids, which ranged from 0.237 miles to 12.245 miles. ψ is given a uniform prior distribution between 0.359 and 19.450 to make the correlation 0.01 at the two endpoints. For the distance-risk function, the parameter α was given a prior distribution around zero such that the natural logarithm of α + 1, which is ln (α + 1), is normally distributed with a mean of zero and a variance of 10. The parameter β was given a uniform distribution from 0 to β_{max} where β_{max} = 3.173. The maximum distance from Staten Island tracts to the Fresh Kills Landfill centroid is 7.566 miles, so that 6.810 miles is 90% of the maximum distance. The choice of β_{max} = 3.173 ensures that the excess relative risk at 6.810 miles from the Fresh Kills Landfill centroid is less than 1% of the excess relative risk at the Fresh Kills Landfill centroid.

For the parameter phi (φ) a variation of the Wakefield and Morris approach was devised to deal with problems where some SIR values were zero and in some cases the least deprived (highest income) tract had a higher SIR than the most deprived tract.[42] These problems arise because the numbers of cases in a tract can be quite small or zero for some cancer sites. First, we found the tracts in the top and bottom 10% of the Z values (most and least deprived). For each combination of cancer site and time period, we found pairs of tracts where the first tract is the top 10%, the second tract is in the bottom 10%, the relative risk (SIR) is higher for the first tract, and the SIR is non-zero for the second tract. From these pairs we computed the maximum ratio of |ln(SIR for tract 1) – ln(SIR for tract 2)| / (Z for tract 1 – Z for tract 2). To ensure that this maximum value K is in the tail of the prior distribution, we gave φ a normal distribution with a mean of zero and a standard deviation of K/3, which depends upon the combination.

The set of priors for the main analysis are called Prior 1. We also considered an alternative prior to evaluate the sensitivity of the predictions to the choice of prior. In Prior 2 all the parameters, including α, have the same prior distributions as in Prior 1 except for β where β_{max} was replaced by 2 × 3.173 = 6.346, giving a much wider distribution. This is a less informative prior than Prior 1.

The MCMC simulation was run using two chains to check that the Markov chain converged. The chains had different initial parameter values. By examining the history of the sequence of parameter values, convergence is indicated when the time series graphs of the sequences of the two different chains appear to be thoroughly mixed after sufficiently many iterations. In addition the Gelman-Rubin test was used to evaluate convergence by evaluating whether the ratio of the widths of the pooled and within central 80% intervals is tending to 1.0 and the pooled and within widths tend to stability. The plots showed that the MCMC iterations converged satisfactorily

[41] Wakefield, J.C and Morris, S.E. 2001. The Bayesian modelling of disease risk in relation to a point source. Journal of American Statistical Association, 96 (435): 77-91.
[42] Wakefield, J.C and Morris, S.E. 2001. The Bayesian modelling of disease risk in relation to a point source. Journal of American Statistical Association, 96 (435): 77-91.

after 10,000 iterations (of each chain). After the burn-in of 10,000 iterations, the model was run for an additional 5,000 iterations, giving 10,000 iterations from the two chains combined. The posterior distributions were calculated from these 10,000 combined iterations.

The results of the Bayesian modeling can be found in Appendix F.

Appendix E. Results of the Analysis of Cancer Incidence

The statistical results of the cancer analysis are provided in this appendix. Table E-1 and Table E-2 provide crude and age-adjusted cancer incidence rates and Standardized Incidence Ratios (SIRs) for men and women, respectively, 15 years of age and over for 1995-2015 overall and by four periods for the Fresh Kills Landfill area, the rest of Staten Island, and the rest of New York City. SIRs are provided for the Fresh Kills area compared with the rest of Staten Island and Staten Island compared with the rest of New York City. Crude total cancer incidence rates and SIRs are provided for children in Table E-3.E-1.

Table E-1. Crude and Age-Adjusted Incidence Rates and SIRs for Men (15 and over).

Specific Cancer Type	Time Period	N (number of cases)			Crude Incidence Rates			Age-Adjusted Incidence Rates			Standardized Incidence Ratios (SIRs) (95% CI)			
		Fresh Kills area	Res of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area vs. Rest of Staten Island	p-value	Staten Island vs. Rest of NYC	p-value
Total Cancer	1995-1999	1,125	3,843	76,658	547.44	661.96	566.07	702.60	718.49	661.05	0.97 (0.91, 1.03)	0.31	1.08 (1.05, 1.11)	0.000
	2000-2004	1,497	4,347	81,469	670.55	692.30	575.46	760.64	735.17	658.63	1.03 (0.97, 1.08)	0.33	1.13 (1.10, 1.16)	0.000
	2005-2009	1,671	4,820	87,772	735.09	730.21	608.25	747.04	746.15	671.54	1.00 (0.95, 1.05)	0.94	1.11 (1.08, 1.14)	0.000
	2010-2015	2,157	6,043	106,698	772.25	735.83	584.88	699.53	690.26	612.86	1.00 (0.96, 1.04)	0.96	1.12 (1.10, 1.15)	0.000
	All years	6,450	19,053	352,597	689.55	708.34	584.04	722.80	719.05	647.62	1.00 (0.98, 1.02)	1.00	1.11 (1.10, 1.13)	0.000
Oral Cavity and Pharynx	1995-1999	21	112	2,435	10.22	19.29	17.98	12.94	20.83	21.08	0.58 (0.36, 0.89)	0.01	0.88 (0.74, 1.04)	0.15
	2000-2004	29	97	2,330	12.99	15.45	16.46	13.27	16.25	18.62	0.87 (0.58, 1.24)	0.50	0.83 (0.69, 0.99)	0.03
	2005-2009	42	110	2,522	18.48	16.66	17.48	18.15	16.52	19.04	1.08 (0.78, 1.46)	0.66	0.89 (0.75, 1.04)	0.15
	2010-2015	58	161	3,156	20.77	19.60	17.30	18.29	18.09	18.02	1.00 (0.76, 1.30)	1.00	1.01 (0.88, 1.15)	0.89
	All years	150	480	10,443	16.04	17.85	17.30	15.98	17.87	19.02	0.90 (0.76, 1.06)	0.22	0.91 (0.84, 0.99)	0.02
Colon	1995-1999	106	360	6,738	51.58	62.01	49.76	72.59	68.76	59.00	1.03 (0.85, 1.25)	0.76	1.17 (1.07, 1.28)	0.00
	2000-2004	129	334	6,694	57.78	53.19	47.28	68.52	57.08	54.55	1.18 (0.98, 1.40)	0.08	1.10 (1.00, 1.21)	0.04

Specific Cancer Type	Time Period	N (number of cases)			Crude Incidence Rates			Age-Adjusted Incidence Rates			Standardized Incidence Ratios (SIRs) (95% CI)			
		Fresh Kills area	Res of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area vs. Rest of Staten Island	p-value	Staten Island vs. Rest of NYC	p-value
	2005-2009	116	310	6,130	51.03	46.96	42.48	52.44	48.76	47.21	1.11 (0.92, 1.33)	0.28	1.05 (0.95, 1.16)	0.30
	2010-2015	115	369	6,818	41.17	44.93	37.37	38.73	42.66	39.50	0.89 (0.74, 1.07)	0.24	1.05 (0.96, 1.14)	0.33
	All years	466	1,373	26,380	49.82	51.04	43.70	53.75	52.41	48.89	1.05 (0.95, 1.15)	0.34	1.09 (1.04, 1.14)	0.00
Rectum	1995-1999	55	144	2,597	26.76	24.80	19.18	34.74	27.85	22.54	1.29 (0.97, 1.67)	0.08	1.27 (1.10, 1.46)	0.00
	2000-2004	46	160	2,762	20.60	25.48	19.51	22.91	27.11	22.41	0.85 (0.62, 1.14)	0.31	1.16 (1.01, 1.33)	0.03
	2005-2009	46	139	2,697	20.24	21.06	18.69	21.51	21.54	20.56	0.97 (0.71, 1.29)	0.91	1.02 (0.88, 1.18)	0.82
	2010-2015	58	161	3,156	20.77	19.60	17.30	18.18	18.58	18.13	1.02 (0.77, 1.32)	0.93	1.02 (0.89, 1.16)	0.81
	All years	205	604	11,212	21.92	22.46	18.57	23.01	22.87	205	1.02 (0.88, 1.17)	0.81	1.11 (1.03, 1.19)	0.00
Liver	1995-1999	18	63	1,830	8.76	10.85	13.51	10.47	11.57	15.83	0.93 (0.55, 1.47)	0.88	0.72 (0.57, 0.90)	0.00
	2000-2004	29	92	2,333	12.99	14.65	16.48	14.84	15.58	18.74	0.93 (0.62, 1.33)	0.78	0.79 (0.66, 0.95)	0.01
	2005-2009	44	142	3,026	19.36	21.51	20.97	18.69	21.45	22.88	0.86 (0.63, 1.16)	0.36	0.90 (0.77, 1.04)	0.15
	2010-2015	75	187	4,079	26.85	22.77	22.36	23.24	20.67	23.13	1.10 (0.86, 1.38)	0.45	0.92 (0.81, 1.04)	0.19
	All years	166	484	11,268	17.75	17.99	18.66	18.25	18.09	20.65	0.98 (0.83, 1.14)	0.81	0.86 (0.79, 0.93)	0.00
Pancreas	1995-1999	35	100	1,917	17.03	17.23	14.16	22.77	18.89	16.81	1.14 (0.79, 1.59)	0.48	1.18 (0.99, 1.40)	0.06
	2000-2004	38	112	2,014	17.02	17.84	14.23	19.54	18.92	16.45	1.01 (0.71, 1.38)	1.00	1.18 (1.00, 1.38)	0.06
	2005-2009	38	135	2,302	16.72	20.45	15.95	17.26	20.50	17.76	0.81 (0.57, 1.11)	0.21	1.13 (0.97, 1.32)	0.11
	2010-2015	62	161	3,220	22.20	19.60	17.65	19.50	18.44	18.65	1.10 (0.84, 1.41)	0.50	1.01 (0.88, 1.15)	0.88
	All years	173	508	9,453	18.50	18.89	15.66	19.56	19.18	17.55	1.00 (0.86, 1.16)	0.99	1.11 (1.03, 1.19)	0.01
Larynx	1995-1999	17	49	1,344	8.27	8.44	9.92	9.62	9.11	11.80	1.06 (0.62, 1.70)	0.87	0.80 (0.62, 1.01)	0.06
	2000-2004	23	70	1,208	10.30	11.15	8.53	10.82	11.60	9.84	0.93 (0.59, 1.40)	0.84	1.18 (0.95, 1.45)	0.12
	2005-2009	24	76	1,108	10.56	11.51	7.68	10.22	11.57	8.51	0.89 (0.57, 1.32)	0.64	1.32 (1.08, 1.61)	0.01

Specific Cancer Type	Time Period	N (number of cases)			Crude Incidence Rates			Age-Adjusted Incidence Rates			Standardized Incidence Ratios (SIRs) (95% CI)			
		Fresh Kills area	Res of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area vs. Rest of Staten Island	p-value	Staten Island vs. Rest of NYC	p-value
	2010-2015	28	78	1,278	10.02	9.50	7.01	8.72	8.78	7.35	0.99 (0.66, 1.43)	1.00	1.19 (0.97, 1.44)	0.09
	All years	92	273	4,938	9.84	10.15	8.18	9.84	10.18	9.12	0.96 (0.77, 1.17)	0.72	1.12 (1.01, 1.24)	0.04
Lung	1995-1999	150	642	10,829	72.99	110.59	79.96	95.38	121.28	94.72	0.78 (0.66, 0.92)	0.00	1.21 (1.13, 1.30)	0.00
	2000-2004	235	646	10,343	105.26	102.88	73.06	119.59	110.08	84.46	1.10 (0.96, 1.25)	0.15	1.33 (1.25, 1.43)	0.00
	2005-2009	222	643	10,242	97.66	97.41	70.98	103.63	101.13	79.39	1.01 (0.88, 1.15)	0.93	1.27 (1.19, 1.36)	0.00
	2010-2015	307	781	11,981	109.91	95.10	65.68	101.52	89.18	69.81	1.10 (0.98, 1.23)	0.10	1.32 (1.24, 1.40)	0.00
	All years	914	2,712	43,395	97.71	100.83	71.88	104.70	102.99	80.66	1.01 (0.95, 1.08)	0.75	1.29 (1.24, 1.33)	0.00
Prostate	1995-1999	280	1,007	21,864	136.25	173.46	161.45	180.50	187.59	192.17	0.96 (0.85, 1.07)	0.46	0.98 0.93, 1.03)	0.45
	2000-2004	395	1,266	25,215	176.93	201.62	178.11	202.56	215.92	207.95	0.92 (0.83, 1.02)	0.11	1.02 (0.97, 1.07)	0.35
	2005-2009	440	1,353	26,814	193.56	204.97	185.82	190.93	209.17	207.89	0.92 (0.83, 1.00)	0.06	0.98 (0.94, 1.03)	0.49
	2010-2015	445	1,500	30,277	159.32	182.65	165.97	136.43	167.15	173.16	0.81 (0.73, 0.88)	0.00	0.91 (0.87, 0.95)	0.00
	All years	1,560	5,126	104,170	166.78	190.57	172.55	171.29	192.50	193.50	0.89 (0.85, 0.93)	0.00	0.97 (0.95, 0.99)	0.01
Bladder	1995-1999	73	296	4,339	35.52	50.99	32.04	47.86	56.34	37.99	0.83 (0.65, 1.04)	0.11	1.44 (1.30, 1.60)	0.00
	2000-2004	119	308	4,439	53.30	49.05	31.35	66.02	52.98	36.28	1.20 (1.00, 1.44)	0.05	1.54 (1.40, 1.70)	0.00
	2005-2009	123	357	4,753	54.11	54.08	32.94	57.05	56.30	36.83	1.02 (0.84, 1.21)	0.88	1.55 (1.41, 1.69)	0.00
	2010-2015	195	442	5,879	69.81	53.82	32.23	64.25	50.93	34.36	1.26 (1.09, 1.45)	0.00	1.60 (1.48, 1.73)	0.00
	All years	510	1,403	19,410	54.52	52.16	32.15	59.88	53.63	36.17	1.10 (1.01, 1.20)	0.03	1.54 (1.47, 1.61)	0.00
Kidney	1995-1999	31	104	2,243	15.08	17.91	16.56	17.29	19.35	19.44	0.94 (0.64, 1.33)	0.82	0.99 (0.83, 1.17)	0.96
	2000-2004	74	168	2,661	33.15	26.76	18.80	35.80	27.61	21.42	1.26 (0.99, 1.58)	0.06	1.40 (1.23, 1.59)	0.00
	2005-2009	75	209	3,183	32.99	31.66	22.06	31.77	31.67	24.28	1.01 (0.80, 1.27)	0.94	1.32 (1.18, 1.49)	0.00
	2010-2015	110	288	4,309	39.38	35.07	23.62	35.18	32.36	24.71	1.05 (0.86, 1.27)	0.62	1.35 (1.22, 1.49)	0.00

Specific Cancer Type	Time Period	N (number of cases)			Crude Incidence Rates			Age-Adjusted Incidence Rates			Standardized Incidence Ratios (SIRs) (95% CI)			
		Fresh Kills area	Res of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area vs. Rest of Staten Island	p-value	Staten Island vs. Rest of NYC	p-value
	All years	290	769	12,396	31.00	28.59	20.53	30.81	28.57	22.73	1.07 (0.95, 1.20)	0.25	1.29 (1.22, 1.37)	0.00
Brain	1995-1999	21	58	1,110	10.22	9.99	8.20	11.22	10.57	8.99	1.11 (0.69, 1.70)	0.69	1.19 (0.94, 1.48)	0.14
	2000-2004	18	52	1,029	8.06	8.28	7.27	8.38	8.60	7.90	1.01 (0.60, 1.60)	1.00	1.08 (0.84, 1.37)	0.54
	2005-2009	18	60	1,074	7.92	9.09	7.44	7.83	9.30	7.88	0.86 (0.51, 1.36)	0.61	1.12 (0.89, 1.40)	0.33
	2010-2015	27	69	1,280	9.67	8.40	7.02	9.48	8.11	7.24	1.12 (0.74, 1.62)	0.62	1.15 (0.93, 1.40)	0.20
	All years	84	239	4,493	8.98	8.89	7.44	9.25	8.98	7.92	1.03 (0.82, 1.27)	0.84	1.14 (1.02, 1.27)	0.03
Thyroid	1995-1999	15	36	550	7.30	6.20	4.06	7.43	6.35	4.40	1.17 (0.66, 1.94)	0.60	1.54 (1.15, 2.03)	0.00
	2000-2004	26	42	760	11.65	6.69	5.37	11.26	6.79	5.72	1.68 (1.10, 2.47)	0.02	1.42 (1.10, 1.80)	0.01
	2005-2009	48	105	1,253	21.12	15.91	8.68	20.02	15.80	9.08	1.29 (0.95, 1.71)	0.10	1.87 (1.59, 2.19)	0.00
	2010-2015	77	190	2,139	27.57	23.14	11.73	25.76	22.20	11.97	1.15 (0.90, 1.43)	0.26	1.95 (1.72, 2.19)	0.00
	All years	166	373	4,702	17.75	13.87	7.79	17.27	13.71	8.16	1.25 (1.07, 1.46)	0.01	1.80 (1.65, 1.96)	0.00
Hodgkin Lymphoma	1995-1999	8	32	561	3.89	5.51	4.14	4.05	5.45	4.11	0.69 (0.30, 1.37)	0.38	1.23 (0.88, 1.68)	0.22
	2000-2004	9	27	628	4.03	4.30	4.44	3.94	4.44	4.39	1.00 (0.46, 1.89)	1.00	0.96 (0.67, 1.33)	0.90
	2005-2009	14	35	643	6.16	5.30	4.46	5.96	5.23	4.49	1.16 (0.64, 1.95)	0.64	1.23 (0.91, 1.63)	0.18
	2010-2015	15	39	792	5.37	4.75	4.34	5.44	4.78	4.31	1.12 (0.63, 1.85)	0.73	1.14 (0.86, 1.49)	0.37
	All years	46	133	2,624	4.92	4.94	4.35	4.85	4.95	4.33	1.00 (0.73, 1.33)	1.00	1.14 (0.98, 1.32)	0.09
Non-Hodgkin Lymphoma	1995-1999	62	180	3,879	30.17	31.01	28.64	35.67	32.97	31.56	1.08 (0.83, 1.38)	0.58	1.04 (0.91, 1.18)	0.57
	2000-2004	69	212	3,613	30.91	33.76	25.52	32.91	34.88	28.08	0.95 (0.74, 1.21)	0.76	1.23 (1.09, 1.38)	0.00
	2005-2009	94	185	3,970	41.35	28.03	27.51	42.79	28.35	29.77	1.49 (1.20, 1.82)	0.00	1.07 (0.94, 1.20)	0.30
	2010-2015	98	296	5,076	35.09	36.04	27.82	32.39	34.51	29.06	0.95 (0.78, 1.16)	0.69	1.17 (1.05, 1.29)	0.00
	All years	323	873	16,538	34.53	32.46	27.39	35.80	32.91	29.65	1.09 (0.98, 1.22)	0.13	1.13 (1.06, 1.19)	0.00

Specific Cancer Type	Time Period	N (number of cases)			Crude Incidence Rates			Age-Adjusted Incidence Rates			Standardized Incidence Ratios (SIRs) (95% CI)			
		Fresh Kills area	Res of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area vs. Rest of Staten Island	p-value	Staten Island vs. Rest of NYC	p-value
Myeloma	1995-1999	21	40	993	10.22	6.89	7.33	13.83	7.67	8.66	1.68 (1.04, 2.57)	0.03	1.02 (0.78, 1.32)	0.89
	2000-2004	20	57	1,181	8.96	9.08	8.34	10.58	9.77	9.63	1.11 (0.68, 1.71)	0.71	1.02 (0.81, 1.28)	0.89
	2005-2009	26	77	1,502	11.44	11.67	10.41	12.14	12.02	11.54	0.99 (0.65, 1.45)	1.00	1.03 (0.84, 1.25)	0.81
	2010-2015	46	120	2,267	16.47	14.61	12.43	14.84	13.72	13.10	1.09 (0.80, 1.45)	0.60	1.07 (0.91, 1.24)	0.42
	All years	113	294	5,943	12.08	10.93	9.84	13.06	11.18	113	1.14 (0.94, 1.37)	0.18	1.04 (0.94, 1.15)	0.44
Leukemia	1995-1999	35	104	1,944	17.03	17.91	14.36	23.30	19.47	16.46	1.07 (0.74, 1.49)	0.74	1.21 (1.02, 1.43)	0.03
	2000-2004	35	101	2,071	15.68	16.09	14.63	17.91	17.08	16.47	1.03 0.72, 1.43)	0.90	1.05 (0.88, 1.24)	0.58
	2005-2009	52	139	2,299	22.88	21.06	15.93	25.10	21.47	17.38	1.09 (0.81, 1.42)	0.59	1.28 (1.10, 1.47)	0.00
	2010-2015	79	231	3,399	28.28	28.13	18.63	26.14	26.59	19.56	0.98 (0.78, 1.22)	0.92	1.37 (1.22, 1.53)	0.00
	All years	201	575	9,713	21.49	21.38	16.09	23.45	21.77	17.66	1.03 (0.89, 1.18)	0.69	1.25 (1.16, 1.34)	0.00
Others	1995-1999	177	516	11,315	86.13	88.88	83.55	102.95	94.41	94.02	1.10 (0.94, 1.27)	0.22	1.03 (0.96, 1.11)	0.43
	2000-2004	203	603	11,962	90.93	96.03	84.49	101.78	100.48	93.88	1.00 (0.87, 1.15)	1.00	1.08 (1.01, 1.16)	0.04
	2005-2009	249	745	14,051	109.54	112.86	97.37	111.57	115.38	105.49	0.98 (0.86, 1.10)	0.73	1.09 (1.02, 1.16)	0.01
	2010-2015	362	970	17,286	129.60	118.11	94.76	121.46	113.50	99.01	1.07 (0.97, 1.19)	0.19	1.17 (1.11, 1.23)	0.00
	All years	991	2,834	54,614	105.95	105.36	90.46	112.05	107.25	98.33	1.04 (0.97, 1.10)	0.26	1.10 (1.07, 1.14)	0.00

Table E-2. Crude and Age-Adjusted Incidence Rates and SIRs for Women (15 and over)

Specific Cancer Type	Time Period	N (number of cases)			Crude Incidence Rates			Age-Adjusted Incidence Rates			Standardized Incident Ratios (SIRs) (95% CI)			
		Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area vs. Rest of Staten Island	p-value	Staten Island vs. Rest of NYC	p-value
Total Cancer	1995-1999	1,233	4,124	82,508	548.99	641.16	525.28	669.92	664.29	581.78	1.00 (0.95, 1.06)	0.94	1.15 (1.12, 1.18)	0.00
	2000-2004	1,491	4,163	84,143	604.18	602.39	514.95	659.95	616.86	561.39	1.08 (1.02, 1.13)	0.00	1.12 (1.10, 1.15)	0.00
	2005-2009	1,773	4,823	89,111	708.16	670.31	538.09	718.39	674.68	578.60	1.06 (1.01, 1.11)	0.02	1.19 (1.16, 1.22)	0.00
	2010-2015	2,314	6,206	113,969	749.16	692.97	549.88	710.16	669.01	577.32	1.05 (1.01, 1.09)	0.02	1.18 (1.15, 1.20)	0.00
	All years	6,811	19,316	369,731	660.86	654.92	533.26	689.94	656.75	574.74	1.05 (1.02, 1.07)	0.00	1.16 (1.15, 1.18)	0.00
Oral Cavity and Pharynx	1995-1999	13	52	1,233	5.79	8.08	7.85	7.37	8.49	8.65	0.85 (0.45, 1.45)	0.67	0.93 (0.72, 1.18)	0.61
	2000-2004	28	56	1,193	11.35	8.10	7.30	12.01	8.16	7.93	1.47 (0.97, 2.12)	0.07	1.18 (0.94, 1.46)	0.15
	2005-2009	14	52	1,252	5.59	7.23	7.56	5.97	7.35	8.09	0.79 (0.43, 1.32)	0.44	0.85 (0.66, 1.08)	0.19
	2010-2015	33	75	1,655	10.68	8.37	7.99	9.93	8.03	8.34	1.23 (0.85, 1.73)	0.27	1.03 (0.84, 1.24)	0.80
	All years	88	235	5,333	8.54	7.97	7.69	8.83	8.01	8.26	1.11 (0.89, 1.37)	0.34	1.00 (0.89, 1.11)	0.98
Colon	1995-1999	116	389	8,215	51.65	60.48	52.30	71.74	62.77	58.94	1.13 (0.93, 1.35)	0.22	1.10 (1.01, 1.20)	0.03
	2000-2004	108	377	7,847	43.76	54.55	48.02	54.71	56.76	53.35	0.95 (0.78, 1.15)	0.64	1.05 (0.96, 1.15)	0.31
	2005-2009	120	321	7,093	47.93	44.61	42.83	52.71	45.89	46.98	1.14 (0.94, 1.36)	0.18	1.01 (0.91, 1.11)	0.90
	2010-2015	130	395	7,296	42.09	44.11	35.20	40.53	43.27	37.70	0.96 (0.80, 1.13)	0.64	1.13 (1.04, 1.23)	0.01
	All years	474	1,482	30,451	45.99	50.25	43.92	51.98	51.31	48.27	1.03 (0.94, 1.13)	0.47	1.07 (1.03, 1.12)	0.00
Rectum	1995-1999	37	133	2,570	16.47	20.68	16.36	21.24	21.37	18.32	1.00 (0.70, 1.37)	1.00	1.18 (1.01, 1.37)	0.04
	2000-2004	30	98	2,548	12.16	14.18	15.59	14.14	14.76	17.22	1.00 (0.68, 1.43)	1.00	0.84 (0.70, 1.00)	0.05
	2005-2009	43	119	2,386	17.17	16.54	14.41	18.16	16.72	15.58	1.05 (0.76, 1.41)	0.80	1.09 (0.93, 1.27)	0.31
	2010-2015	46	124	2,618	14.89	13.85	12.63	14.13	13.39	13.28	1.04 (0.76, 1.39)	0.81	1.01 (0.86, 1.17)	0.91
	All years	156	474	10,122	15.14	16.07	14.60	16.26	16.24	15.88	1.02 (0.87, 1.20)	0.78	1.03 (0.95, 1.11)	0.51

Specific Cancer Type	Time Period	N (number of cases)			Crude Incidence Rates			Age-Adjusted Incidence Rates			Standardized Incident Ratios (SIRs) (95% CI)			
		Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area vs. Rest of Staten Island	p-value	Staten Island vs. Rest of NYC	p-value
Liver	1995-1999	8	29	924	3.56	4.51	5.88	4.64	4.69	6.57	1.08 (0.47, 2.13)	0.92	0.71 (0.50, 0.98)	0.04
	2000-2004	12	35	977	4.86	5.06	5.98	5.61	5.31	6.58	1.06 (0.55, 1.85)	0.92	0.81 (0.60, 1.08)	0.17
	2005-2009	16	48	1,135	6.39	6.67	6.85	7.30	6.85	7.43	1.00 (0.57, 1.62)	1.00	0.90 (0.69, 1.15)	0.45
	2010-2015	18	74	1,767	5.83	8.26	8.53	5.82	7.90	8.97	0.68 (0.40, 1.07)	0.11	0.81 (0.65, 0.99)	0.04
	All years	54	186	4,803	5.24	6.31	6.93	5.93	6.41	7.55	0.88 (0.66, 1.15)	0.38	0.81 (0.71, 0.92)	0.00
Pancreas	1995-1999	31	114	2,375	13.80	17.72	15.12	18.75	18.52	17.04	1.03 (0.70, 1.46)	0.92	1.10 (0.93, 1.29)	0.28
	2000-2004	38	126	2,558	15.40	18.23	15.65	18.43	18.99	17.46	0.98 (0.69, 1.34)	0.98	1.09 (0.93, 1.27)	0.28
	2005-2009	44	146	2,622	17.57	20.29	15.83	18.85	20.99	17.45	0.92 (0.66, 1.23)	0.62	1.18 (1.02, 1.36)	0.03
	2010-2015	61	166	3,505	19.75	18.54	16.91	20.02	17.97	18.16	1.04 (0.80, 1.34)	0.78	1.01 (0.89, 1.16)	0.84
	All years	174	552	11,060	16.88	18.72	15.95	19.22	19.05	17.59	0.99 (0.85, 1.15)	0.93	1.09 (1.01, 1.17)	0.03
Larynx	1995-1999	3	17	376	1.34	2.64	2.39	1.57	2.86	2.68	0.56 (0.12, 1.65)	0.45	0.93 (0.57, 1.43)	0.85
	2000-2004	9	18	341	3.65	2.60	2.09	3.50	2.74	2.29	1.48 (0.68, 2.81)	0.32	1.31 (0.86, 1.91)	0.20
	2005-2009	5	18	334	2.00	2.50	2.02	1.90	2.41	2.17	0.75 (0.24, 1.75)	0.69	1.09 (0.69, 1.63)	0.74
	2010-2015	7	28	310	2.27	3.13	1.50	2.01	2.95	1.55	0.69 (0.28, 1.42)	0.41	1.73 (1.21, 2.41)	0.00
	All years	24	81	1,361	2.33	2.75	1.96	2.26	2.72	2.12	0.85 (0.55, 1.27)	0.50	1.26 (1.03, 1.52)	0.03
Lung	1995-1999	162	540	8,756	72.13	83.95	55.74	91.80	87.49	62.47	1.04 (0.89, 1.22)	0.62	1.42 (1.32, 1.53)	0.00
	2000-2004	197	529	8,954	79.83	76.55	54.80	89.73	79.10	60.67	1.13 (0.98, 1.30)	0.09	1.37 (1.27, 1.47)	0.00
	2005-2009	222	610	9,277	88.67	84.78	56.02	91.11	86.60	61.43	1.06 (0.93, 1.21)	0.40	1.44 (1.35, 1.54)	0.00
	2010-2015	267	748	11,534	86.44	83.52	55.65	81.74	81.32	59.49	1.01 (0.90, 1.14)	0.83	1.37 (1.29, 1.46)	0.00
	All years	848	2,427	38,521	82.28	82.29	55.56	87.75	82.93	60.77	1.06 (0.99, 1.13)	0.11	1.40 (1.35, 1.45)	0.00
Breast	1995-1999	374	1,236	24,561	166.52	192.16	156.36	192.07	198.55	173.31	0.96 (0.86, 1.06)	0.39	1.14 (1.09, 1.20)	0.00

Specific Cancer Type	Time Period	N (number of cases)			Crude Incidence Rates			Age-Adjusted Incidence Rates			Standardized Incident Ratios (SIRs) (95% CI)			
		Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area vs. Rest of Staten Island	p-value	Staten Island vs. Rest of NYC	p-value
	2000-2004	451	1,176	23,748	182.75	170.17	145.34	189.73	172.31	157.49	1.12 (1.02, 1.23)	0.02	1.13 (1.07, 1.18)	0.00
	2005-2009	520	1,268	24,733	207.69	176.23	149.35	203.40	174.22	159.50	1.16 (1.06, 1.26)	0.00	1.14 (1.09, 1.20)	0.00
	2010-2015	646	1,699	32,522	209.14	189.71	156.91	195.49	180.49	164.11	1.06 (0.98, 1.14)	0.17	1.12 (1.08, 1.17)	0.00
	All years	1,991	5,379	105,564	193.18	182.38	152.25	195.04	181.18	163.39	1.07 (1.03, 1.12)	0.00	1.13 (1.11, 1.16)	0.00
Bladder	1995-1999	28	118	1,905	12.47	18.35	12.13	16.70	19.39	13.60	0.88 (0.59, 1.28)	0.58	1.38 (1.16, 1.62)	0.00
	2000-2004	41	115	1,925	16.61	16.64	11.78	19.08	17.32	13.11	1.11 (0.80, 1.50)	0.55	1.38 (1.17, 1.61)	0.00
	2005-2009	48	133	1,841	19.17	18.48	11.12	20.68	19.07	12.29	1.07 (0.79, 1.42)	0.69	1.60 (1.38, 1.85)	0.00
	2010-2015	53	127	2,184	17.16	14.18	10.54	16.60	13.90	11.36	1.21 (0.91, 1.58)	0.20	1.30 (1.11, 1.50)	0.00
	All years	170	493	7,855	16.49	16.72	11.33	18.15	16.99	12.49	1.08 (0.92, 1.25)	0.35	1.41 (1.30, 1.52)	0.00
Kidney	1995-1999	24	74	1,496	10.69	11.50	9.52	13.34	12.09	10.57	1.08 (0.69, 1.60)	0.77	1.16 (0.94, 1.41)	0.17
	2000-2004	41	82	1,710	16.61	11.87	10.47	18.41	12.40	11.47	1.51 (1.08, 2.04)	0.02	1.21 (1.00, 1.44)	0.05
	2005-2009	45	115	1,963	17.97	15.98	11.85	18.40	16.21	12.84	1.13 (0.83, 1.51)	0.44	1.30 (1.11, 1.52)	0.00
	2010-2015	55	152	2,491	17.81	16.97	12.02	16.81	16.37	12.63	1.02 (0.77, 1.32)	0.94	1.30 (1.13, 1.49)	0.00
	All years	165	423	7,660	16.01	14.34	11.05	16.77	14.37	11.96	1.15 (0.98, 1.34)	0.08	1.25 (1.15, 1.36)	0.00
Brain	1995-1999	13	60	1,094	5.79	9.33	6.96	6.18	9.67	7.52	0.69 (0.37, 1.19)	0.22	1.18 (0.93, 1.49)	0.18
	2000-2004	21	41	1,002	8.51	5.93	6.13	9.27	5.99	6.52	1.56 (0.96, 2.38)	0.07	1.05 (0.80, 1.34)	0.75
	2005-2009	17	58	955	6.79	8.06	5.77	6.40	8.18	6.07	0.84 (0.49, 1.34)	0.54	1.29 (1.01, 1.61)	0.04
	2010-2015	22	65	1,138	7.12	7.26	5.49	6.63	7.14	5.66	0.96 (0.60, 1.45)	0.96	1.24 (0.99, 1.53)	0.06
	All years	73	224	4,189	7.08	7.59	6.04	7.10	7.61	6.37	0.97 (0.76, 1.22)	0.85	1.19 (1.06, 1.33)	0.00
Thyroid	1995-1999	26	63	1,792	11.58	9.79	11.41	11.45	9.95	11.63	1.18 (0.77, 1.72)	0.46	0.88 (0.71, 1.09)	0.26
	2000-2004	65	125	2,467	26.34	18.09	15.10	24.44	17.85	15.37	1.44 (1.11, 1.84)	0.01	1.30 (1.12, 1.50)	0.00

Specific Cancer Type	Time Period	N (number of cases)			Crude Incidence Rates			Age-Adjusted Incidence Rates			Standardized Incident Ratios (SIRs) (95% CI)			
		Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area vs. Rest of Staten Island	p-value	Staten Island vs. Rest of NYC	p-value
	2005-2009	135	327	4,350	53.92	45.45	26.27	52.56	44.64	26.75	1.15 (0.96, 1.36)	0.13	1.75 (1.59, 1.91)	0.00
	2010-2015	210	537	7,475	67.99	59.96	36.07	64.50	58.68	36.44	1.10 (0.96, 1.26)	0.17	1.65 (1.54, 1.77)	0.00
	All years	436	1,052	16,084	42.30	35.67	23.20	40.38	35.16	23.62	1.16 (1.05, 1.28)	0.00	1.54 (1.47, 1.62)	0.00
Hodgkin Lymphoma	1995-1999	11	24	491	4.90	3.73	3.13	4.94	3.86	3.05	1.35 (0.68, 2.42)	0.40	1.32 (0.92, 1.84)	0.13
	2000-2004	6	36	561	2.43	5.21	3.43	2.12	5.24	3.37	0.46 (0.17, 1.00)	0.05	1.34 (0.96, 1.81)	0.08
	2005-2009	7	20	580	2.80	2.78	3.50	3.10	2.86	3.44	1.02 (0.41, 2.09)	1.00	0.83 (0.55, 1.21)	0.38
	2010-2015	12	41	705	3.89	4.58	3.40	4.03	4.64	3.34	0.85 (0.44, 1.49)	0.71	1.35 (1.01, 1.77)	0.04
	All years	36	121	2,337	3.49	4.10	3.37	3.58	4.13	3.30	0.85 (0.60, 1.18)	0.38	1.21 (1.03, 1.42)	0.02
Non-Hodgkin Lymphoma	1995-1999	61	174	3,255	27.16	27.05	20.72	34.20	27.47	22.60	1.19 (0.91, 1.52)	0.21	1.28 (1.12, 1.46)	0.00
	2000-2004	56	161	3,317	22.69	23.30	20.30	24.60	23.76	22.02	1.05 (0.79, 1.37)	0.74	1.10 (0.96, 1.26)	0.17
	2005-2009	71	200	3,652	28.36	27.80	22.05	28.96	28.45	23.66	1.05 (0.82, 1.32)	0.72	1.20 (1.06, 1.35)	0.00
	2010-2015	115	249	4,533	37.23	27.80	21.87	36.68	27.07	23.00	1.31 (1.08, 1.57)	0.01	1.27 (1.14, 1.41)	0.00
	All years	303	784	14,757	29.40	26.58	21.28	31.40	26.78	22.88	1.17 (1.04, 1.31)	0.01	1.22 (1.15, 1.29)	0.00
Myeloma	1995-1999	11	53	1,200	4.90	8.24	7.64	5.44	8.47	8.56	0.75 (0.37, 1.33)	0.40	0.95 (0.73, 1.21)	0.72
	2000-2004	19	49	1,371	7.70	7.09	8.39	8.86	7.23	9.27	1.21 (0.73, 1.89)	0.46	0.83 (0.65, 1.06)	0.14
	2005-2009	22	73	1,480	8.79	10.15	8.94	8.68	10.43	9.76	0.90 (0.56, 1.36)	0.71	1.03 (0.83, 1.26)	0.79
	2010-2015	24	91	2,085	7.77	10.16	10.06	7.38	9.80	10.68	0.74 (0.48, 1.10)	0.16	0.86 (0.71, 1.03)	0.10
	All years	76	266	6,136	7.37	9.02	8.85	7.85	9.14	9.66	0.87 (0.69, 1.09)	0.24	0.91 (0.82, 1.01)	0.08
Leukemia	1995-1999	19	92	1,781	8.46	14.30	11.34	10.89	14.83	12.54	0.72 (0.43, 1.13)	0.17	1.12 (0.92, 1.35)	0.26
	2000-2004	37	100	1,921	14.99	14.47	11.76	17.93	15.15	12.84	1.21 (0.85, 1.66)	0.29	1.21 (1.02, 1.43)	0.03
	2005-2009	44	122	1,913	17.57	16.96	11.55	19.35	17.33	12.49	1.06 (0.77, 1.42)	0.74	1.41 (1.21, 1.64)	0.00

Specific Cancer Type	Time Period	N (number of cases)			Crude Incidence Rates			Age-Adjusted Incidence Rates			Standardized Incident Ratios (SIRs) (95% CI)			
		Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area vs. Rest of Staten Island	p-value	Staten Island vs. Rest of NYC	p-value
	2010-2015	68	169	2,801	22.02	18.87	13.51	21.80	18.44	14.29	1.15 (0.89, 1.46)	0.27	1.35 (1.18, 1.53)	0.00
	All years	168	483	8,416	16.30	16.38	12.14	17.96	16.58	13.15	1.07 (0.91, 1.24)	0.43	1.29 (1.19, 1.39)	0.00
Others	1995-1999	296	956	20,484	131.79	148.63	130.41	157.60	153.84	143.73	1.02 (0.91, 1.15)	0.71	1.08 (1.02, 1.14)	0.01
	2000-2004	332	1,039	21,703	134.53	150.35	132.82	147.38	153.79	144.43	0.94 (0.85, 1.05)	0.31	1.06 (1.00, 1.12)	0.04
	2005-2009	400	1,193	23,545	159.76	165.80	142.18	160.87	166.46	152.66	0.96 (0.87, 1.06)	0.47	1.09 (1.04, 1.14)	0.00
	2010-2015	547	1,466	29,350	177.09	163.70	141.61	166.05	157.65	148.31	1.05 (0.96, 1.14)	0.28	1.08 (1.03, 1.13)	0.00
	All years	1,575	4,654	95,082	152.82	157.80	137.14	159.47	158.14	147.48	1.00 (0.95, 1.05)	0.96	1.08 (1.05, 1.10)	0.00

Table E-3. Crude Incidence Rates and SIRs for Children.

Specific Cancer Type	Time Period	N (number of cases)			Crude Incidence Rates			Standardized Incidence Ratios (SIRs) (95% CI)			
		Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area vs. Rest of Staten Island	p-value	Staten Island vs. Rest of NYC	p-value
Total Cancer	1995-1999	24	52	1,160	19.92	15.42	15.37	1.29 (0.83, 1.92)	0.26	1.08 (0.85, 1.35)	0.53
	2000-2004	18	51	1,228	15.23	14.47	16.37	1.05 (0.62, 1.66)	0.89	0.90 (0.70, 1.13)	0.39
	2005-2009	22	57	1,238	20.48	16.75	17.88	1.22 (0.77, 1.85)	0.40	0.99 (0.78, 1.23)	0.97
	2010-2015	23	81	1,583	18.69	20.08	18.74	0.93 (0.59, 1.40)	0.83	1.05 (0.86, 1.28)	0.62
	All years	87	241	5,209	18.54	16.81	17.12	1.11 (0.89, 1.37)	0.36	1.01 (0.90, 1.12)	0.92

Trend analysis results (beta) and their significance (*p*-values) are provided in the tables below for men (Table E-4), women (Table E-5), and children (Table E-6) for the former Fresh Kills Landfill area, rest of Staten Island, and rest of New York City for 1995-2015. A *p*-value less than 0.05 indicates a statistically significant increase when the beta is positive or decrease when the beta is negative in incidence rates over time.

Table E-4. *p*-Values for Trends for Men (15 and over), 1995 to 2015.

Specific Cancer	Fresh Kills Landfill area		Rest of Staten Island		Rest of New York City	
	Beta	p-value	Beta	p-value	Beta	p-value
Total Cancer	-0.535	0.885	-1.511	0.587	-2.624	0.330
Oral Cavity and Pharynx	0.404	0.091	-0.149	0.527	-0.169	0.152
Colon	-2.290	0.021	-1.676	0.014	-1.280	0.005
Rectum	-0.986	0.091	-0.649	0.033	-0.294	0.050
Liver	0.819	0.000	0.638	0.084	0.502	0.050
Pancreas	-0.229	0.329	0.002	0.988	0.133	0.105
Larynx	-0.067	0.506	-0.025	0.892	-0.284	0.010
Lung	0.033	0.978	-2.045	0.001	-1.550	0.007
Prostate	-2.865	0.340	-1.387	0.583	-1.159	0.533
Bladder	0.778	0.373	-0.255	0.360	-0.202	0.111
Kidney	0.955	0.267	0.829	0.077	0.360	0.037
Brain	-0.108	0.519	-0.130	0.193	-0.102	0.065
Thyroid	1.238	0.010	1.101	0.041	0.507	0.012
Hodgkin Lymphoma	0.119	0.215	-0.024	0.648	0.013	0.446
Non-Hodgkin Lymphoma	-0.012	0.983	-0.030	0.934	-0.111	0.495
Myeloma	0.094	0.668	0.395	0.003	0.296	0.007
Leukemia	0.308	0.441	0.506	0.169	0.200	0.087
Others	1.276	0.070	1.388	0.090	0.505	0.387

Table E-5. *p*-Values for Trends for Women (15 and over), 1995 to 2015.

Specific Cancer	Fresh Kills Landfill area		Rest of Staten Island		Rest of New York City	
	Beta	p-value	Beta	p-value	Beta	p-value
Total Cancer	3.453	0.207	1.404	0.649	0.082	0.940
Oral Cavity and Pharynx	0.035	0.913	-0.041	0.427	-0.014	0.698
Colon	-1.856	0.039	-1.340	0.027	-1.364	0.005
Rectum	-0.336	0.352	-0.426	0.188	-0.326	0.009
Liver	0.098	0.406	0.217	0.011	0.157	0.072
Pancreas	0.084	0.201	0.003	0.987	0.065	0.062
Larynx	-0.006	0.954	-0.001	0.984	-0.068	0.027
Lung	-0.569	0.187	-0.216	0.646	-0.160	0.154
Breast	0.452	0.496	-0.988	0.451	-0.480	0.547
Bladder	0.018	0.940	-0.290	0.233	-0.147	0.006
Kidney	0.196	0.454	0.322	0.085	0.145	0.090
Brain	-0.031	0.859	-0.104	0.558	-0.117	0.031
Thyroid	3.628	0.016	3.357	0.020	1.669	0.016
Hodgkin Lymphoma	-0.031	0.830	0.001	0.994	0.018	0.322
Non-Hodgkin Lymphoma	0.243	0.700	0.067	0.781	0.054	0.475
Myeloma	0.105	0.556	0.138	0.354	0.133	0.005
Leukemia	0.660	0.063	0.252	0.033	0.097	0.237
Others	0.762	0.356	0.453	0.495	0.418	0.324

Table E-6. *p*-Values for Trends for Children, 1995 to 2015.

Specific Cancer	Fresh Kills Landfill area		Rest of Staten Island		Rest of New York City	
	Beta	p-value	Beta	p-value	Beta	p-value
Total Cancer	0.030	0.319	0.319	0.916	0.225	0.007

Appendix F. Results of the Bayesian Analysis

Table F-1 presents the results of Stone's test (previously described in Appendix D-6.2) for each combination of demographic group, cancer site, and time period.

Table F-1. Stone's Non-parametric Test.

Demographic Group	Cancer Site	Years	P-value
Adults (>= 15)	Bladder	1995-2004	0.119
Adults (>= 15)	Bladder	2005-2015	0.001
Adults (>= 15)	Kidney	1995-2004	0.078
Adults (>= 15)	Kidney	2005-2015	0.093
Adults (>= 15)	Lung	1995-2004	0.001
Adults (>= 15)	Lung	2005-2015	0.007
Adults (>= 15)	Non-Hodgkin Lymphoma	1995-2004	0.173
Adults (>= 15)	Non-Hodgkin Lymphoma	2005-2015	0.003
Adults (>= 15)	Thyroid	1995-2004	0.001
Adults (>= 15)	Thyroid	2005-2015	0.001
Children (< 15)	Total Cancers	1995-2004	0.001
Children (< 15)	Total Cancers	2005-2015	0.039
Women (>= 15)	Breast	1995-2004	0.002
Women (>= 15)	Breast	2005-2015	0.001

Table F-2 gives the posterior distributions for the parameters α, β, and ρ as well as the estimated Prob ($\alpha > 0$). The combinations that show the strongest relationship between cancer cases and proximity to the landfill have the highest value of Prob ($\alpha > 0$). For Prior 1, the main model, the strongest relationship is therefore for thyroid cancer in adults during 2005-2015. Consistently for both prior distributions, the strongest relationships are for bladder and thyroid cancer in adults during 2005-2015. There is quite a bit of sensitivity to the choice of Prior for α and β (especially at the 97.5^{th} percentile) but very little sensitivity for ρ. All other tables and figures are based on the Prior 1 results.

Table F-3 gives the posterior distributions for all the parameters.

Table F-2. Selected Posterior Distributions for Alternative Priors.

Demographic Group	Cancer Site	Years	Prior*	α			β			ρ			Prob (α > 0)
				50th	2.5th	97.5th	50th	2.5th	97.5th	50th	2.5th	97.5th	
Adults (>= 15)	Bladder	1995-2004	1	0.093	-0.996	146.2	0.567	0.028	2.952	1.308	1.172	1.458	0.536
Adults (>= 15)	Bladder	1995-2004	2	0.145	0.995	69.30	0.797	0.037	6.094	1.293	1.110	1.450	0.596
Adults (>= 15)	Bladder	2005-2015	1	0.442	-0.737	1.602	2.792	0.224	3.160	1.369	1.238	1.524	0.951
Adults (>= 15)	Bladder	2005-2015	2	0.711	0.250	1.638	5.590	3.159	6.317	1.087	0.759	1.392	1.000
Adults (>= 15)	Kidney	1995-2004	1	-0.017	-0.998	72.32	0.827	0.036	3.051	1.063	0.874	1.272	0.495
Adults (>= 15)	Kidney	1995-2004	2	0.429	-0.991	14.08	2.837	0.071	6.141	1.017	0.722	1.241	0.725
Adults (>= 15)	Kidney	2005-2015	1	0.123	-0.997	107.2	0.565	0.030	2.931	1.329	1.193	1.469	0.565
Adults (>= 15)	Kidney	2005-2015	2	0.327	-0.991	22.12	3.542	0.057	6.258	1.258	0.991	1.452	0.807
Adults (>= 15)	Lung	1995-2004	1	1.020	-0.889	11.63	1.102	0.147	2.310	0.00355	0.00193	0.00515	0.940
Adults (>= 15)	Lung	1995-2004	2	0.902	-0.951	16.60	1.096	0.122	4.332	1.450	1.349	1.547	0.911
Adults (>= 15)	Lung	2005-2015	1	0.200	-0.996	125.2	0.542	0.027	2.983	1.405	1.314	1.491	0.623
Adults (>= 15)	Lung	2005-2015	2	0.238	-0.986	32.12	3.943	0.064	6.244	1.346	1.123	1.483	0.843
Adults (>= 15)	Non-Hodgkin Lymphoma	1995-2004	1	0.129	-0.998	85.70	0.583	0.028	2.951	1.167	1.046	1.296	0.563
Adults (>= 15)	Non-Hodgkin Lymphoma	1995-2004	2	0.191	-0.994	77.26	0.966	0.038	6.175	1.151	0.868	1.299	0.673
Adults (>= 15)	Non-Hodgkin	2005-2015	1	0.362	-0.991	58.81	1.261	0.049	3.087	1.053	0.953	1.151	0.762

	Lymphoma												
Adults (>= 15)	Non-Hodgkin Lymphoma	2005-2015	2	0.380	-0.457	76.56	3.390	0.075	6.229	1.015	0.750	1.142	0.940
Adults (>= 15)	Thyroid	1995-2004	1	0.708	-0.957	15.23	1.991	0.083	3.136	0.874	0.711	1.051	0.869
Adults (>= 15)	Thyroid	1995-2004	2	1.687	0.409	6.554	5.538	2.462	6.307	0.525	0.215	0.888	1.000
Adults (>= 15)	Thyroid	2005-2015	1	0.523	0.073	4.699	2.326	0.546	3.143	1.435	1.292	1.584	0.980
Adults (>= 15)	Thyroid	2005-2015	2	0.612	0.233	1.202	5.096	1.649	6.288	1.219	0.938	1.503	0.999
Children (<15)	Total Cancers	1995-2004	1	0.384	-0.997	33.14	1.084	0.048	3.063	0.721	0.526	0.954	0.596
Children (<15)	Total Cancers	1995-2004	2	0.634	-0.995	32.14	2.754	0.082	6.126	0.676	0.338	0.928	0.742
Children (<15)	Total Cancers	2005-2015	1	-0.326	-0.997	114.1	0.680	0.028	2.882	0.943	0.757	1.129	0.388
Children (<15)	Total Cancers	2005-2015	2	-0.106	-0.996	62.85	0.943	0.040	6.009	0.922	0.692	1.179	0.445
Females (>=15)	Breast	1995-2004	1	-0.279	-0.998	151.3	0.453	0.022	2.499	1.090	1.019	1.152	0.413
Females (>=15)	Breast	1995-2004	2	0.021	-0.997	97.45	0.612	0.031	6.154	1.084	0.919	1.153	0.523
Females (>=15)	Breast	2005-2015	1	0.200	-0.995	133.3	0.556	0.027	3.086	1.073	1.007	1.134	0.659
Females (>=15)	Breast	2005-2015	2	0.189	-0.958	23.90	3.523	0.074	6.190	1.037	0.923	1.119	0.880

Table F-3. Posterior Distributions for All Parameters.

Demographic Group	Cancer Site	Years	Parameter	50th	2.5th	97.5th
Adults (>= 15)	Bladder	1995-2004	α	0.093	-0.996	146.2
Adults (>= 15)	Bladder	1995-2004	β	0.567	0.028	2.952
Adults (>= 15)	Bladder	1995-2004	ρ	1.308	1.172	1.458
Adults (>= 15)	Bladder	1995-2004	τv	1064	57.5	6094
Adults (>= 15)	Bladder	1995-2004	τu	502.2	30.46	5378
Adults (>= 15)	Bladder	1995-2004	ψ	10.05	0.798	18.98
Adults (>= 15)	Bladder	1995-2004	φ	-0.0029	-0.0054	-0.0003
Adults (>= 15)	Bladder	2005-2015	α	0.442	-0.7368	1.602
Adults (>= 15)	Bladder	2005-2015	β	2.792	0.2243	3.16
Adults (>= 15)	Bladder	2005-2015	ρ	1.369	1.238	1.524
Adults (>= 15)	Bladder	2005-2015	τv	397.5	37.01	4715
Adults (>= 15)	Bladder	2005-2015	τu	566.7	43.89	5376
Adults (>= 15)	Bladder	2005-2015	ψ	10.26	0.9639	18.97
Adults (>= 15)	Bladder	2005-2015	φ	-6.04E-04	-0.002489	0.001257
Adults (>= 15)	Kidney	1995-2004	α	-0.01687	-0.9976	72.32
Adults (>= 15)	Kidney	1995-2004	β	0.827	0.03644	3.051
Adults (>= 15)	Kidney	1995-2004	ρ	1.063	0.8744	1.272
Adults (>= 15)	Kidney	1995-2004	τv	19.64	4.872	4968
Adults (>= 15)	Kidney	1995-2004	τu	33.75	5.071	3564
Adults (>= 15)	Kidney	1995-2004	ψ	10.91	1.611	19
Adults (>= 15)	Kidney	1995-2004	φ	-0.001421	-0.005839	0.0031
Adults (>= 15)	Kidney	2005-2015	α	0.1228	-0.9973	107.2
Adults (>= 15)	Kidney	2005-2015	β	0.565	0.02954	2.931
Adults (>= 15)	Kidney	2005-2015	ρ	1.329	1.193	1.469
Adults (>= 15)	Kidney	2005-2015	τv	315.8	29.42	3804
Adults (>= 15)	Kidney	2005-2015	τu	455.1	33.7	4559
Adults (>= 15)	Kidney	2005-2015	ψ	10.32	0.7301	18.98

Adults (>= 15)	Kidney	2005-2015	φ	5.07E-04	-0.001971	0.003073
Adults (>= 15)	Lung	1995-2004	α	1.020	-0.8889	11.63
Adults (>= 15)	Lung	1995-2004	β	1.102	0.1474	2.31
Adults (>= 15)	Lung	1995-2004	ρ	1.453	1.36	1.545
Adults (>= 15)	Lung	1995-2004	τv	367.2	51.07	4586
Adults (>= 15)	Lung	1995-2004	τu	329.8	51.94	3964
Adults (>= 15)	Lung	1995-2004	ψ	10.44	1.444	19.01
Adults (>= 15)	Lung	1995-2004	φ	0.00355	0.001925	0.005149
Adults (>= 15)	Lung	2005-2015	α	0.200	-0.9964	125.2
Adults (>= 15)	Lung	2005-2015	β	0.542	0.02653	2.983
Adults (>= 15)	Lung	2005-2015	ρ	1.405	1.314	1.491
Adults (>= 15)	Lung	2005-2015	τv	301.5	43.4	4831
Adults (>= 15)	Lung	2005-2015	τu	127.0	41.98	3816
Adults (>= 15)	Lung	2005-2015	ψ	11.70	2.337	19.05
Adults (>= 15)	Lung	2005-2015	φ	0.002	1.02E-04	0.003347
Adults (>= 15)	Non-Hodgkin Lymphoma	1995-2004	α	0.129	-0.9976	85.7
Adults (>= 15)	Non-Hodgkin Lymphoma	1995-2004	β	0.583	0.02833	2.951
Adults (>= 15)	Non-Hodgkin Lymphoma	1995-2004	ρ	1.167	1.046	1.296
Adults (>= 15)	Non-Hodgkin Lymphoma	1995-2004	τv	223.8	20.61	3635
Adults (>= 15)	Non-Hodgkin Lymphoma	1995-2004	τu	493.8	18.44	6124
Adults (>= 15)	Non-Hodgkin Lymphoma	1995-2004	ψ	9.912	1.024	18.92
Adults (>= 15)	Non-Hodgkin Lymphoma	1995-2004	φ	8.31E-04	-0.001737	0.003534
Adults (>= 15)	Non-Hodgkin Lymphoma	2005-2015	α	0.362	-0.991	58.81
Adults (>= 15)	Non-Hodgkin Lymphoma	2005-2015	β	1.261	0.04876	3.087
Adults (>= 15)	Non-Hodgkin Lymphoma	2005-2015	ρ	1.053	0.9525	1.151
Adults (>= 15)	Non-Hodgkin Lymphoma	2005-2015	τv	924.7	115.2	5872
Adults (>= 15)	Non-Hodgkin Lymphoma	2005-2015	τu	853.3	114.4	4712
Adults (>= 15)	Non-Hodgkin Lymphoma	2005-2015	ψ	10.22	0.95	19.02
Adults (>= 15)	Non-Hodgkin Lymphoma	2005-2015	φ	-0.002454	-0.004572	-2.60E-04
Adults (>= 15)	Thyroid	1995-2004	α	0.7082	-0.9572	15.23

Adults (>= 15)	Thyroid	1995-2004	β	1.991	0.08343	3.136
Adults (>= 15)	Thyroid	1995-2004	ρ	0.8739	0.7111	1.051
Adults (>= 15)	Thyroid	1995-2004	τv	587.9	28.72	5018
Adults (>= 15)	Thyroid	1995-2004	τu	568.8	30.55	4335
Adults (>= 15)	Thyroid	1995-2004	ψ	10.09	1.108	19
Adults (>= 15)	Thyroid	1995-2004	φ	-0.007024	-0.01126	-0.002549
Adults (>= 15)	Thyroid	2005-2015	α	0.523	0.07319	4.699
Adults (>= 15)	Thyroid	2005-2015	β	2.326	0.5463	3.143
Adults (>= 15)	Thyroid	2005-2015	ρ	1.435	1.292	1.584
Adults (>= 15)	Thyroid	2005-2015	τv	197.2	29.69	3982
Adults (>= 15)	Thyroid	2005-2015	τu	377.3	30.95	4663
Adults (>= 15)	Thyroid	2005-2015	ψ	11.13	1.862	19.05
Adults (>= 15)	Thyroid	2005-2015	φ	-0.003421	-0.005545	-0.001249
Children (<15)	Total Cancers	1995-2004	α	0.384	-0.997	33.14
Children (<15)	Total Cancers	1995-2004	β	1.084	0.0485	3.063
Children (<15)	Total Cancers	1995-2004	ρ	0.721	0.526	0.954
Children (<15)	Total Cancers	1995-2004	τv	637.6	13.66	5313
Children (<15)	Total Cancers	1995-2004	τu	1.575	0.894	3.433
Children (<15)	Total Cancers	1995-2004	ψ	8.046	1.607	18.82
Children (<15)	Total Cancers	1995-2004	φ	-3.07E-04	-0.00534	0.00478
Children (<15)	Total Cancers	2005-2015	α	-0.3263	-0.997	114.1
Children (<15)	Total Cancers	2005-2015	β	0.680	0.028	2.882
Children (<15)	Total Cancers	2005-2015	ρ	0.943	0.757	1.129
Children (<15)	Total Cancers	2005-2015	τv	4.420	2.106	2366
Children (<15)	Total Cancers	2005-2015	τu	202.9	2.540	3699
Children (<15)	Total Cancers	2005-2015	ψ	10.60	1.424	18.99
Children (<15)	Total Cancers	2005-2015	φ	-3.73E-04	-0.00516	0.00446
Females (>=15)	Breast	1995-2004	α	-0.279	-0.998	151.3
Females (>=15)	Breast	1995-2004	β	0.453	0.02162	2.499
Females (>=15)	Breast	1995-2004	ρ	1.090	1.019	1.152

Females (>=15)	Breast	1995-2004	τv	622.1	92.49	4927
Females (>=15)	Breast	1995-2004	τu	1.00E+03	100.1	5714
Females (>=15)	Breast	1995-2004	ψ	10.43	1.126	18.97
Females (>=15)	Breast	1995-2004	φ	-0.001138	-0.002699	2.61E-04
Females (>=15)	Breast	2005-2015	α	0.1998	-0.9948	133.3
Females (>=15)	Breast	2005-2015	β	0.5562	0.02735	3.086
Females (>=15)	Breast	2005-2015	ρ	1.073	1.007	1.134
Females (>=15)	Breast	2005-2015	τv	376.6	71.05	3951
Females (>=15)	Breast	2005-2015	τu	368.9	71.04	4461
Females (>=15)	Breast	2005-2015	ψ	10.90	1.120	19.03
Females (>=15)	Breast	2005-2015	φ	-0.00123	-0.00249	1.08E-04

To allow an easy summary comparison between earlier and later time periods, Table F-4 compares the posterior distributions of α including the estimated Prob (α > 0).

Table F-4. Comparison of alpha for Different Time Periods.

Demographic Group	Cancer Site	Years	50th	2.5th	97.5th	Prob (α > 0)
Adults (>= 15)	Bladder	1995-2004	0.093	-0.996	146.2	0.536
Adults (>= 15)	Bladder	2005-2015	0.442	-0.7368	1.602	0.951
Adults (>= 15)	Kidney	1995-2004	-0.01687	-0.9976	72.32	0.495
Adults (>= 15)	Kidney	2005-2015	0.1228	-0.9973	107.2	0.565
Adults (>= 15)	Lung	1995-2004	1.02	-0.8889	11.63	0.940
Adults (>= 15)	Lung	2005-2015	0.2003	-0.9964	125.2	0.623
Adults (>= 15)	Non-Hodgkin Lymphoma	1995-2004	0.1292	-0.9976	85.7	0.563
Adults (>= 15)	Non-Hodgkin Lymphoma	2005-2015	0.3619	-0.991	58.81	0.762
Adults (>= 15)	Thyroid	1995-2004	0.7082	-0.9572	15.23	0.869
Adults (>= 15)	Thyroid	2005-2015	0.5226	0.07319	4.699	0.980
Children (<15)	Total Cancers	1995-2004	0.3843	-0.9973	33.14	0.596
Children (<15)	Total Cancers	2005-2015	-0.3263	-0.997	114.1	0.388
Females (>=15)	Breast	1995-2004	-0.2794	-0.9976	151.3	0.413
Females (>=15)	Breast	2005-2015	0.1998	-0.9948	133.3	0.659

Tables F-5a through F-5n show the predicted medians (and 95% credible intervals) for the total numbers of cases in the former Freshkills Landfill study area and in Staten Island (including the former Fresh Kills Landfill study area). These were calculated by using the posterior distribution to simulate cancer cases in each tract, which were then summed over tracts. The results for "Proximity to landfill" use the full model described above. The results for "Landfill effect removed" use the same posterior distributions as the full model but replace α by 0 so that the hypothetical effect of removing the landfill can be evaluated; the values for the other parameters are not changed. The model "excess cases" represents the difference between the simulated numbers of cases for "Proximity to landfill" and for "Landfill effect removed" and so can be thought of as the excess cases that might be attributable to the existence of a distance-risk pattern.

Table F-5a. Predicted Medians (95% Credible Intervals) for Bladder Cancer in Adults (>= 15) in 1995-2004.

Model	Fresh Kills Landfill area	Staten Island
Proximity to landfill	257 (220 - 300)	1095 (1006 - 1189)
Landfill effect removed	253 (215 - 290)	1089 (987 - 1187)
Excess cases	4 (-45 - 63)	6 (-91 - 113)

Table F-5b. Predicted Medians (95% Credible Intervals) for Bladder Cancer in Adults (>= 15) in 2005-2015.

Model	Fresh Kills Landfill area	Staten Island
Proximity to landfill	422 (361 - 481)	1477 (1373 - 1585)
Landfill effect removed	343 (292 - 407)	1350 (1207 - 1525)
Excess cases	80 (-23 - 160)	126 (-49 - 278)

Table F-c. Predicted Medians (95% Credible Intervals) for Breast Cancer in Women (>=15) in 1995-2004.

Model	Fresh Kills Landfill area	Staten Island
Proximity to landfill	809 (743 - 875)	3235 (3075 - 3392)
Landfill effect removed	808 (744 - 875)	3234 (3075 - 3397)
Excess cases	0 (-79 - 84)	0 (-160 - 160)

Table F-5d. Predicted Medians (95% Credible Intervals) for Breast Cancer in Women (>= 15) in 2005-2015.

Model	Fresh Kills Lanfill area	Staten Island
Proximity to landfill	1130 (1043 - 1228)	4132 (3959 - 4311)
Landfill effect removed	1104 (987 - 1196)	4099 (3806 - 4301)
Excess cases	21 (-87 - 198)	34 (-164 - 323)

Table F-5e. Predicted Medians (95% Credible Intervals) for Kidney Cancer in Adults (>= 15) in 1995-2004.

Model	Fresh Kills Landfill area	Staten Island
Proximity to landfill	158 (126 - 195)	596 (532 - 665)
Landfill effect removed	152 (109 - 189)	589 (483 - 665)
Excess cases	4 (-36 - 71)	8 (-67 - 117)

Table F-5f. Predicted Medians (95% Credible Intervals) for Kidney Cancer in Adults (>= 15) in 2005-2015.

Model	Fresh Kills Landfill area	Staten Island
Proximity to landfill	278 (239 - 320)	1048 (962 - 1138)
Landfill effect removed	272 (232 - 313)	1041 (943 - 1137)
Excess cases	5 (-44 - 64)	7 (-88 - 108)

Table F-5g. Predicted Medians (95% Credible Intervals) for Lung Cancer in Adults (>= 15) in 1995-2004.

Model	Fresh Kills Landfill area	Staten Island
Proximity to landfill	744 (673 - 819)	3100 (2948 - 3255)
Landfill effect removed	689 (619 - 760)	3042 (2872 - 3209)
Excess cases	55 (-42 - 156)	58 (-112 - 234)

Table F-5h. Predicted Medians (95% Credible Intervals) for Lung Cancer in Adults (>= 15) in 2005-2015.

Model	Fresh Kills Landfill area	Staten Island
Proximity to landfill	993 (913 - 1083)	3799 (3631 - 3972)
Landfill effect removed	976 (876 - 1061)	3779 (3546 - 3960)
Excess cases	15 (-80 - 159)	22 (-163 - 256)

Table F-5i. Predicted Medians (95% Credible Intervals) for Non-Hodgkin Lymphoma in Adults (>= 15) in 1995-2004.

Model	Fresh Kills Landfill area	Staten Island
Proximity to landfill	241 (205 - 282)	974 (888 - 1062)
Landfill effect removed	237 (199 - 274)	968 (870 - 1057)
Excess cases	4 (-42 - 58)	5 (-82 - 106)

Table F-5j. Predicted Medians (95% Credible Intervals) for Non-Hodgkin Lymphoma in Adults (>= 15) in 2005-2015.

Model	Fresh Kills Landfill area	Staten Island
Proximity to landfill	361 (312 - 420)	1308 (1210 - 1408)
Landfill effect removed	337 (287 - 384)	1277 (1139 - 1394)
Excess cases	22 (-42 - 108)	31 (-85 - 171)

Table F-5k. Predicted Medians (95% Credible Intervals) for Thyroid Cancer in Adults (>= 15) in 1995-2004.

Model	Fresh Kills Landfill area	Staten Island
Proximity to landfill	125 (96 - 159)	398 (346 - 455)
Landfill effect removed	102 (74 - 132)	369 (289 - 440)
Excess cases	22 (-20 - 71)	30 (-41 - 114)

Table F-5l. Predicted Medians (95% Credible Intervals) for Thyroid Cancer in Adults (>= 15) in 2005-2015.

Model	Fresh Kills Landfill area	Staten Island
Proximity to landfill	486 (425 - 549)	1624 (1517 - 1739)
Landfill effect removed	406 (344 - 473)	1514 (1349 - 1679)
Excess cases	81 (-16 - 174)	110 (-49 - 280)

Table F-5m. Predicted Medians (95% Credible Intervals) for Total Cancers in Children (< 15) in 1995-2004.

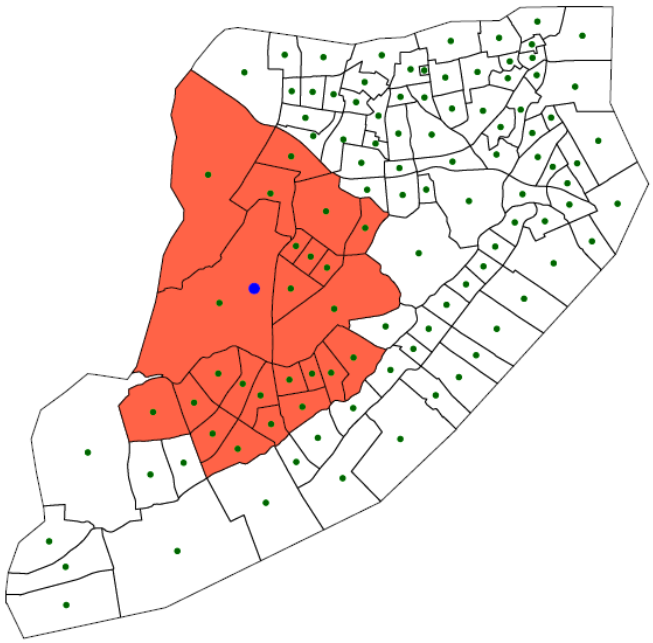
Model	Fresh Kills Landfill area	Staten Island
Proximity to landfill	81 (58 - 107)	290 (244 - 338)
Landfill effect removed	73 (37 - 105)	280 (204 - 338)
Excess cases	6 (-27 - 56)	9 (-46 - 92)

Table F-5n. Predicted Medians (95% Credible Intervals) for Total Cancers in Children (< 15) in 2005-2015.

Model	Fresh Kills Landfill area	Staten Island
Proximity to landfill	87 (65 - 112)	366 (314 - 422)
Landfill effect removed	88 (64 - 117)	368 (314 - 428)
Excess cases	-1 (-59 - 55)	-1 (-33 - 28)

The map below illustrates the former Fresh Kills Landfill study area and Staten Island centroids used for the Bayesian analysis.

Figure 2. Former Fresh Kills Landfill study area and Staten Island Centroid Map



Appendix G. Results of the Analysis of Cause of Death

The statistical results of the cause of death analysis are provided in this appendix. Table G-1 and Table G-2 provide death counts, age-adjusted mortality rates and Mortality Rate Ratios (MRRs) for non-injury or poisoning cause death and death due to chronic lower respiratory disease for men and women, respectively, ages 15 years and older. Age-adjusted mortality rates are provided for 1995-2015 overall and by four periods for the former Fresh Kills Landfill study area, the rest of Staten Island, and the rest of New York City. MRRs and their associated *p*-values are provided for the former Fresh Kills Landfill study area compared with the rest of Staten Island.

Table G-1. Fresh Kills Landfill study area and rest of the New York City Mortality by Selected Causes, New York City 1995-2015, Counts and Age Adjusted Mortality Rates per 100,000 Population for Men.

Specific Cause of Death	Time period	N (number of cases)			Age-Adjusted Mortality Rate			Age-adjusted Mortality Rate Ratios (MRRs) (95% CI)	
		Fresh Kills area	Rest of Staten Island-	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area vs. Rest of Staten Island	*p*-value
Chronic Lower Respiratory Diseases	1995-1999	35	236	3.487	40.3	47.1	30.8	0.86 (0.68, 1.04)	>0.05
	2000-2004	51	279	3,356	38.0	42.5	24.7	0.89 (0.72, 1.07)	>0.05
	2005-2009	45	198	2,957	35.4	30.7	22.0	1.15 (0.89, 1.41)	>0.05
	2010-2015	66	352	4,232	41.9	45.1	26.6	0.93 (0.77, 1.08)	>0.05
	All years	197	1,065	14,032	–	–	–	–	–
Non-Injury or Poisoning Causes	1995-1999	1,145	6,547	130,685	1269.7	1322.5	1158.7	0.96 (0.95, 0.97)	<0.05
	2000-2004	1,294	6,465	115,807	911.3	957.3	829.0	0.95 (0.94, 0.97)	>0.05
	2005-2009	1,332	6,181	105,359	959.9	934.1	763.5	1.03 (1.01, 1.04)	>0.05
	2010-2015	1,648	7,315	122,410	1032.3	934.5	750.2	1.10 (1.09, 1.12)	<0.05
	All years	5, 419	26,508	474,261	–	–	–	–	–

Table G-2. Fresh Kills Landfill study area, rest of Staten Island, and rest of the New York City Mortality by Selected Causes, New York City 1995-2015, Counts and Age Adjusted Mortality Rate Ratios per 100,000 New York City residents, Women.

Specific Cause of Death	Time period	N (number of cases)			Age-Adjusted Mortality Rate			Age-adjusted Mortality Rate Ratios (MRRs) (95% CI)	
		Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area	Rest of Staten Island	Rest of NYC	Fresh Kills area vs. Rest of Staten Island	*p*-value
Chronic Lower Respiratory Diseases	1995-1999	45	275	3,883	20.3	23.5	15.3	0.86 (0.63, 1.10)	>0.05
	2000-2004	59	358	3,888	28.2	34.5	17.5	0.82 (0.65, 0.98)	<0.05
	2005-2009	57	279	3,656	26.9	26.7	16.3	1.01 (0.78, 1.23)	>0.05
	2010-2015	74	395	4,963	29.3	31.1	18.3	0.94 (0.76, 1.12)	>0.05
	All years	235	1,307	16,390	–	–	–	–	–
Non-Injury or Poisoning Causes	1995-1999	1,275	7,315	142,173	585.1	620.7	559.2	0.94 (0.93, 0.96)	<0.05
	2000-2004	1,461	7,520	132,421	675.4	708.8	591.1	0.95 (0.94, 0.97)	<0.05
	2005-2009	1,509	7,167	119,632	696.7	670.5	531.8	1.04 (1.02, 1.06)	<0.05
	2010-2015	1,886	8,181	136,736	730.2	637.1	502.2	1.15 (1.13, 1.16)	<0.05
	All years	6,131	30,183	530,962	–	–	–	–	–

Appendix H. Asthma

H-1. Data Availability and Associated Definitions

Asthma-related emergency department visits and hospitalizations on a neighborhood level were available for adults from 2012 to 2014 and children (ages 5 to 17) for 2014 to 2016. Data were sourced from SPARCS Deidentified Hospital Discharge Data and presented on the Neighborhood Tabulation Area (NTA) level. NTAs were created by the NYC Department of City Planning for projecting data over small geographies while maintaining a base population of 15,000 residents by using whole census tracts from the 2010 Census as building blocks. There are 18 NTAs in Staten Island with six NTAs intersecting the Freshkills area (Appendix C; Figure C-1).

An emergency department visit is included if it has an ICD-9 principal diagnosis code of 493 or an ICD-10 principal diagnosis code of J45. New York hospitals began using the ICD-10 system on October 1, 2015. Because changes in diagnostic coding for classifying adult asthma is not comparable before and after 2015, data are unavailable for 2015 and the most recent data are from 2012-2014. There were no changes to diagnostic coding of children with asthma, so the most recent childhood asthma data are from 2014-2016.

H-2. Results

Table H-1 provides the rates of asthma-related emergency department visits and hospitalizations for both adults (ages 18 and older) and children (ages 5 to 17). For adults, rates for both emergency department visits and hospitalizations are age-adjusted. Rates are provided for New York City as a whole and separately for five boroughs. Rates are also provided for specific Staten Island neighborhoods. Using NTA definitions, six neighborhoods listed in Table H-1 were determined to intersect the former Fresh Kills Landfill study area by visual inspection of the overlaid geographies. These include: Annadale-Huguenot-Prince's Bay-Eltingville, Arden Heights, Great Kills, New Springville-Bloomfield-Travis, Rossville-Woodrow, and Todt Hill-Emerson Hill-Heartland Village-Lighthouse Hill. Table H-1 also provides poverty data for New York City, each of the five boroughs, and Staten Island NTAs. Poverty, defined as the estimated percentage of individuals falling under 100% of the federal poverty level, was available by NTA levels from the American Community Survey, 2012-2016. Poverty was considered due to disparities seen in asthma outcomes between low and high socioeconomic status areas in urban settings. Low socioeconomic status or poverty may be an indicator of poorer housing quality, including increases in allergens and irritants, such as cockroach frass, mold, or tobacco, which have been linked to negative asthma outcomes.[43]

[43] Bryant-Stephens, T. 2009. Journal of Allergy and Clinical Immunology, 123(6): 1199-1206.

Table H-1. Asthma-related Emergency Department Visits and Hospitalizations among Adults and Children, in New York City, by Borough and Neighborhood Tabulation Areas.

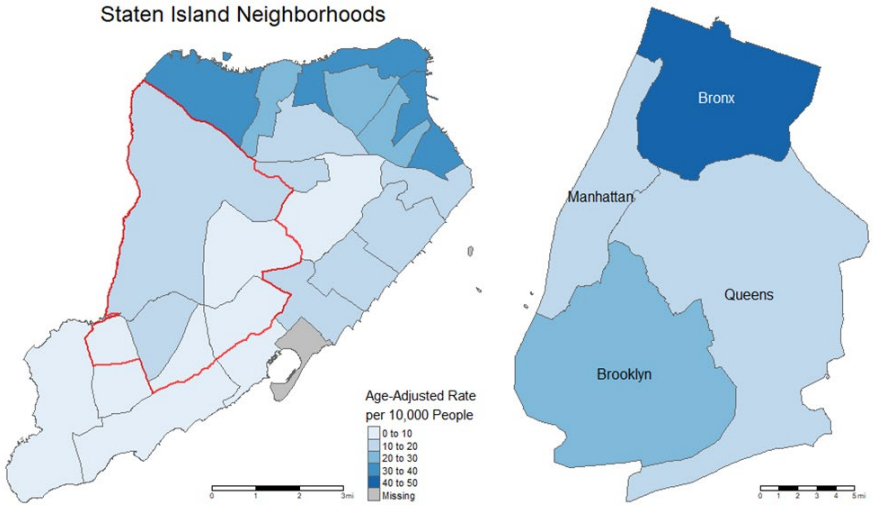
Geography	Age-Adjusted Emergency Department Visits[a], Adults	Age-Adjusted Hospitalizations[a], Adults	Emergency Department Visits[b], Children (Ages 5-17)	Hospitalizations[b], Children (Ages 5-17)	Poverty[c]
New York City	115.6	23.2	223.7	29.9	20.3
Bronx	222.4	46.8	406.7	58.3	30.5
Brooklyn	124.0	24.4	190.6	25.5	22.7
Manhattan	105.8	18.6	267.5	28.7	17.6
Queens	61.9	13.5	129.6	17.5	14.6
Staten Island	77.7	17.8	95.5	13.5	12.9
Annadale-Huguenot-Prince's Bay-Eltingville	24.7	8.4	30.3	2.9	5.5
Arden Heights	39.7	15.7	33.6	2.3[d]	7.0
Charleston-Richmond Valley-Tottenville	35.7	9.7	45.7	6.7[d]	6.2
Grasmere-Arrochar-Ft. Wadsworth	94.7	18.8	100.6	8.4[d]	12.5
Great Kills	32.7	8.2	35.5	6.9	7.3
Grymes Hill-Clifton-Fox Hills	107.9	22.2	139.5	13.6	22.9
Mariner's Harbor-Arlington-Port Ivory-Graniteville	160.4	37.4	176.3	34.2	22.2
New Brighton-Silver Lake	89.0	20.0	104.6	14.6	15.2
New Dorp-Midland Beach	51.4	14.7	48.6	12.2	9.2
New Springville-Bloomfield-Travis	46.3	12.4	53.7	5.4[d]	9.9
Oakwood-Oakwood Beach	49.4	15.0	39.3	3.0[d]	7.2
Old Town-Dongan Hills-South Beach	58.0	15.0	60.4	4.6[d]	13.7
Port Richmond	112.2	24.7	155.5	23.4	20.7
Rossville-Woodrow	34.3	8.7	48.2	9.6[d]	11.4
Stapleton-Rosebank	171.1	39.8	162.2	18.4	22.4

Todt Hill-Emerson Hill-Heartland Village-Lighthouse Hill	31.8	7.0	35.8	5.1[d]	8.5
West New Brighton-New Brighton-St. George	207.6	38.4	278.3	42.9	26.7
Westerleigh	47.8	12.6	60.5	7.3[d]	9.0

[a]Rate per 10,000 residents. Data obtained from SPARCS inpatient and outpatient data 2012-2014.
[b]Rate per 10,000 residents. Data obtained from SPARCS inpatient and outpatient data 2014-2016.
[c]Estimated percentage of individuals falling under 100% of the federal poverty level 2012-2016, data from the American Community Survey.
[d]Estimates based on small numbers should be interpreted with caution.

Figure H-1 illustrates the rates of adult age-adjusted asthma-related hospitalizations in Staten Island neighborhoods (*i.e.,* NTAs) and New York City's boroughs from 2012 to 2014. The area outlined in red on the map of Staten Island neighborhoods represents the former Fresh Kills Landfill study area. The rate of asthma-related hospitalizations increases as the color shading darkens. A similar illustration of the rates of asthma-related emergency department visits is provided in Section III of the report as part of the discussion of the asthma findings for this study.

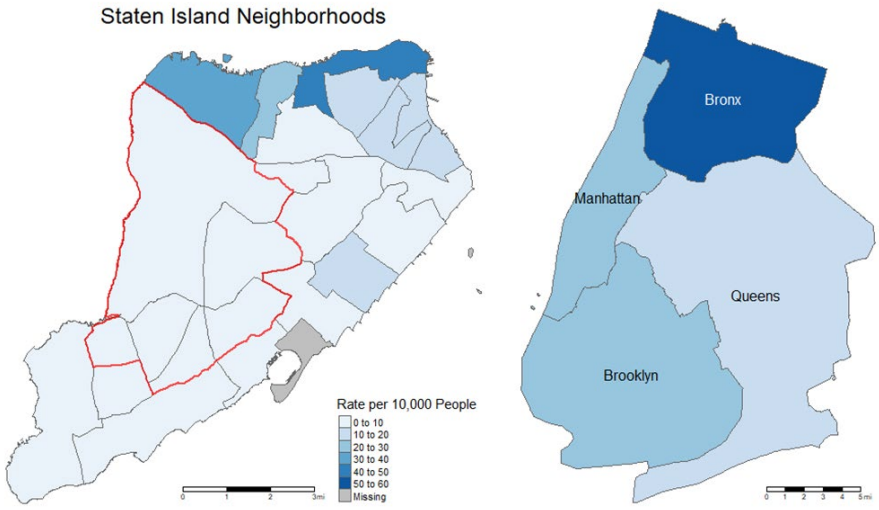
Figure H-1. Age-Adjusted Adult Asthma-related Hospitalizations in Staten Island Neighborhoods and New York City (2012 to 2014)



Note: Red line in figure denotes former Fresh Kills Landfill study area.

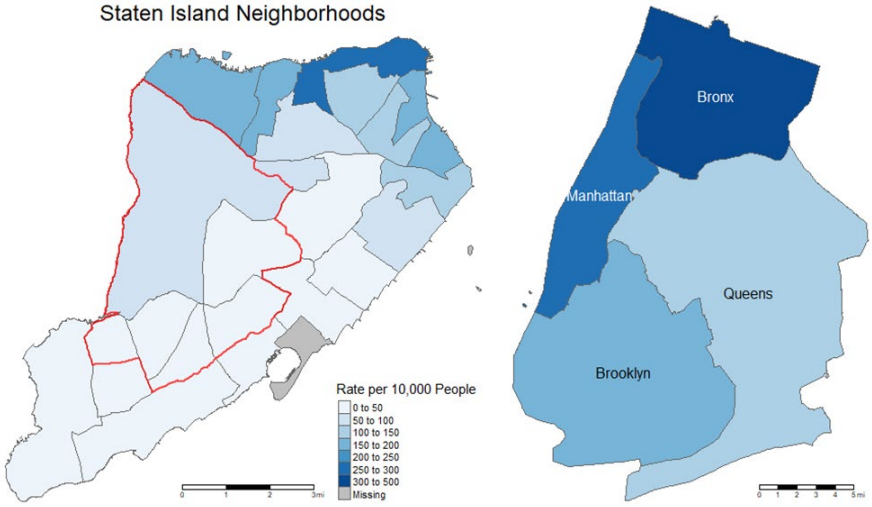
Figure H-2 and Figure H-3 illustrate the rates of asthma-related hospitalizations and emergency department visits, respectively, for children in Staten Island neighborhoods (*i.e.,* NTAs) and New York City's boroughs from 2014 to 2016. In Figure H-3, areas within the red outlined area representing the former Fresh Kills Landfill study area are shaded with lightest color indicating age-adjusted rates of asthma-related hospitalizations of 0 to 10 per 10,000 people. In Figure H-4, age-adjusted rates of asthma-related emergency department visits are shaded to indicate rates of either 0 to 10 per 10,000 people or 10 to 20 per 10,000 people.

Figure H-2. Child (Ages 5 to 17) Asthma-related Hospitalizations in Staten Island Neighborhoods and New York City 2014 to 2016



Note: Red line in figure denotes former Fresh Kills landfill study area.

Figure H-3. Child (Ages 5 to 17) Asthma-related Emergency Department Visits in Staten Island Neighborhoods and New York City 2014 to 2016



Note: Red line in figure denotes former Fresh Kills landfill study area.

Appendix I. Demographic and Behavioral Cancer Risk Factors

I-1. Prevalence

The prevalence of risk factors of interest were obtained from the NYC Health Department Community Health Survey from 2002 to 2016. Survey questions corresponding to relevant variables were not asked in all years and data are presented where it is available. Results are presented by United Hospital Fund (UHF) Neighborhoods, the smallest available geography, which are aggregated from ZIP Codes. Single year data from the Community Health Survey for 2002-2016 combined the 4 UHFs in Staten Island into two: Northern Staten Island and Southern Staten Island.Several estimates of risk factor prevalence were not stable at the UHF Neighborhood geographic scale because of small numbers and estimates were not available stratified by UHF Neighborhood and sex. These limitations highlight the difficulty of obtaining detailed survey information at finer geographic levels.

We aimed to provide prevalence estimates for risk factors of interest in the former Fresh Kills Landfill study area, Staten Island excluding the former Fresh Kills Landfill study area, and New York City excluding Staten Island. Within Staten Island, we were only able to compare Northern and Southern Staten Island, as determined by UHF Neighborhood definitions, with other geographies. The former Fresh Kills Landfill study area lies in Southern Staten Island. Data were available on the following risk factors:

- tobacco smoking;
- heavy drinking;
- obesity;
- physical activity; and
- fruit and vegetable consumption.

Two other behavioral factors of interest include the use of a personal doctor and screening for breast cancer. The use of personal doctor captures access to health care, insurance availability and information about awareness about screening timing and availability. Awareness about early detection benefits, improved therapies, and access to care may lead to increased detection and an apparent elevation in rates that is mainly due to increased screening rather than a true increase in disease.

Table I-1 provides prevalence data for the risk factors and behavioral factors listed above among residents of New York City, Staten Island, and two Staten Island neighborhoods: Northern Staten Island and Southern Staten Island. As noted in the table, the area designated as Southern Staten Island overlaps with the former Fresh Kills Landfill study area. From 2002 to 2016 there was a marked decrease in the prevalence of current smoking among adults and a slight increase in

obesity prevalence across all geographies. However, the prevalence of other risk factors remained relatively stable over time.

In Staten Island, the prevalence of obesity was generally higher compared to all of New York City. This increase was primarily seen in Northern Staten Island while obesity in Southern Staten Island was still slightly elevated compared to New York City. The rate of cigarette smoking in Staten Island is elevated compared to New York City, especially during the period from 2002 to 2008. The rate of fruit and vegetable consumption was generally consistent between New York City and Northern Staten Island, but individuals in Southern Staten Island reported fruit or vegetable consumption at a higher rate than both New York City and Northern Staten Island. Rates of physical activity in Northern Staten Island were not as consistent across years, however, Southern Staten Island reported slightly higher rates of physical activity compared to New York City. Breast cancer screening rates in Northern and Southern Staten Island fluctuated around the New York City rate over the survey period. The rate of having a personal doctor or physician was higher in Southern Staten Island over the entire period compared to New York City. This was generally true in Northern Staten Island, although there was more fluctuation in yearly estimates.

New York City saw an increase in the number of respondents reporting they felt they had a health care professional they could consider their personal doctor, but this trend was not as strong in Staten Island. Between the two UHF Neighborhoods, risk factor prevalence rates fluctuated over time with North Staten Island consuming less fruit and vegetables than South Staten Island.

Table I-1. Risk Factor Prevalence among Adults (18 Years and Older) in New York City, Staten Island, and Staten Island Neighborhoods.

Risk Factor	Year	NYC[a]	95% CI[b]	Staten Island[c]	95% CI	Northern Staten Island[d]	95% CI	Southern Staten Island[e]	95% CI
Tobacco Smoking, Current Smoker	2002	21.5	20.5-22.6	27.2	23-31.8	27.5	22-33.7	26.7	21.1-33.2
	2004	18.3	17.4-19.3	28.8	24.5-33.6	22.2	17.5-27.7	33.5	27.2-40.4
	2006	17.5	16.6-18.5	27.2	23.2-31.6	27.7	22-34.3	27.2	22-33.1
	2008	15.8	14.6-17.1	21.0	16.5-26.4	20.6	15.1-27.5	21.4	15.1-29.4
	2010	14.0	12.9-15.3	13.5	10.2-17.6	14.8	9.8-21.7	12.8	8.7-18.3
	2012	15.5	14.4-16.8	16.5	12.8-21.1	19.8	14.1-27.1	14.2	9.6-20.5
	2014	13.9	12.8-14.9	16.6	12.8-21.2	21.2	14.7-29.6	13.6	9.7-18.8
	2016	13.1	12.2-14.1	15.9	11.7-21.1	14.6	8.9-23.1	16.9	11.5-24.1
Heavy Drinking, Yes	2002	4.8	4.3-5.4	4.8	2.9-7.7	**5.3**[f]	2.8-9.9	**4.4**	2.1-8.9
	2004	4.2	3.7-4.8	5.5	3.5-8.7	5.3	2.9-9.4	**5.7**	2.9-10.8
	2007	5.1	4.5-5.8	6.1	3.9-9.3	7.5	4.4-12.5	**5.1**	2.4-10.6
	2008	4.3	3.6-5	3.1	2-4.9	**3.2**	1.5-6.7	3.0	1.7-5.3
	2010	5.6	4.8-6.5	**3.5**	1.9-6.2	**(-)**[g]	(-)	**3.4**	1.9-6.1
	2012	5.9	5.1-6.7	**5.3**	2.6-10.5	**5.1**	2.6-9.8	**(-)**	(-)
	2014	5.1	4.5-5.8	4.3	2.5-7.4	**6.1**	2.8-12.5	**3.2**	1.5-6.9
	2016	4.7	4.1-5.5	**2.9**	1.5-5.5	**4.6**	1.9-10.3	**1.8**	0.6-5.4
Physical Activity in the last 30 days, Yes	2002	73.7	72.6-74.9	79.2	74.9-82.9	77.5	71.2-82.7	80.6	74.9-85.3
	2004	72.4	71.2-73.5	74.7	70.2-78.7	67.3	60.7-73.3	79.6	73.2-84.8
	2008	72.7	71.3-74	70.2	64.8-75.1	68.0	60.7-74.4	71.5	63.6-78.3
	2010	72.7	71.2-74.1	75.6	70-80.4	77.5	70.4-83.3	74.3	66.2-81.1
	2012	77.8	76.4-79.1	80.4	76-84.2	83.5	76.8-88.6	78.9	72.8-84
	2014	75.9	74.6-77.1	78.2	73.7-82.1	76.9	69-83.3	79.3	73.8-83.9
	2016	71.6	70.3-72.8	71.9	65.9-77.3	**64.1**	53.1-73.8	77.4	71.1-82.7
Breast Cancer Screening (Female, Age 40+), Yes	2002	77.0	75-78.8	78.4	70.7-84.5	85.0	76.4-90.9	**74.7**	63.1-83.5
	2004	77.0	75.3-78.7	79.1	71.5-85.2	75.3	65.6-83	82.4	71.9-89.5
	2006	75.2	73.5-76.8	72.6	65.6-78.6	76.8	65.5-85.2	69.8	60.9-77.4
	2008	77.8	76-79.6	79.8	72.8-85.4	81.8	72.4-88.5	69.6	64.2-74.4
	2010	76.7	74.6-78.7	77.9	71.2-83.4	76.2	65.7-84.2	78.5	69.7-85.3

	2012	74.5	72.2-76.6	77.1	68.4-83.9	69.1	55.1-80.2	81.2	69.8-89
	2014	74.9	72.7-77.1	72.5	64.7-79.2	**68.1**	55.8-78.3	75.4	65.5-83.2
Personal Doctor, Yes	2002	74.8	73.7-75.9	84.3	80.4-87.6	78.7	72.6-83.7	88.5	83.5-92.2
	2004	79.1	78.1-80.2	87.1	83.2-90.2	84.5	78.8-88.9	88.8	83.1-92.7
	2006	79.0	77.9-80	83.7	79.8-87	80.2	73.7-85.4	86.0	80.7-90
	2008	84.4	83.1-85.6	90.2	86.7-92.9	87.0	80.6-91.5	92.4	88-95.3
	2011	83.1	81.5-84.5	**92.2**	86-95.8	**92.5**	85.4-96.2)	**95.3**	89.4-98
	2012	81.7	80.3-83	87.3	82.6-90.8	84.4	76.1-90.2	89.4	83.6-93.3
	2014	84.4	83.3-85.5	89.3	85.2-92.4	87.4	80.4-92.1	90.7	85.4-94.2
	2016	83.2	82.1-84.3	76.9	70.5-82.3	**66.0**	55-75.5	84.1	76.5-89.5
No Fruit or Vegetable Consumption	2002	14.3	13.4-15.2	16.1	12.8-20.1	19.8	15-25.6	13.5	9.5-19
	2004	14.1	13.2-15	14.0	10.7-18	17.2	12.6-23.2	11.9	7.7-17.8
	2008	12.9	11.9-14.1	11.1	8.2-14.8	15.9	11.1-22.2	7.5	4.9-11.4
	2010	11.6	10.6-12.8	9.1	6.5-12.6	10.0	6.3-15.6	8.4	5.2-13.2
	2012	12.5	11.4-13.6	10.0	7.1-14	14.6	9.5-21.7	7.1	4.2-11.9
	2014	12.2	11.2-13.2	10.8	7.9-14.5	10.7	6.8-16.3	10.6	7-15.6
	2016	13.0	12-14	10.1	6.7-14.9	15.2	9-24.7	6.1	3.6-10.3
Obesity	2002	18.2	17.2-19.2	18.4	14.9-22.6	18.2	13.6-23.9	18.7	13.9-24.6
	2004	21.7	20.7-22.7	26.6	22.2-31.4	27.7	21.5-35	26.1	20.5-32.6
	2006	21.1	20.1-22.1	22.7	19.1-26.7	26.4	20.6-33.2	20.0	15.7-25.1
	2008	22.6	21.4-23.9	26.6	22.5-31.3	33.8	26.6-41.8	21.8	17.3-27
	2010	23.4	22.1-24.8	27.6	22.9-32.8	32.2	25-40.3	24.5	18.6-31.4
	2012	24.2	22.8-25.5	32.0	26.7-37.8	34.5	26.4-43.7	30.6	24-38.2
	2014	24.7	23.4-26	29.2	24.7-34.1	28.5	21.7-36.5	29.5	23.8-36
	2016	23.6	22.5-24.9	25.6	20.9-31	21.5	15.3-29.4	29.0	22.6-36.3

[a] NYC is New York City
[b] CI is Confidence Interval
[c] SI is Staten Island
[d] Northern Staten Island refers to the United Hospital Fund (UHF) 34 neighborhood definition (UHF Code 501/502)
[e] Southern Staten Island refers to the United Hospital Fund (UHF) 34 neighborhood definition (UHF Code 503/504)
[f] Bolded values denote the estimate should be interpreted with caution. Estimate's Relative Standard Error (a measure of estimate precision) is greater than 30% or the sample size is less than 50, or the 95% Confidence Interval half width is greater than ten, making the estimate potentially unreliable.
[g] (-) indicates that data were not available for those selected years.

Demographic information for New York City and Staten Island for the period 2010 to 2016 were obtained from the U.S. Census Bureau's American FactFinder using ACS table S0501. American FactFinder draws estimates of demographic information from the American Community Survey 5-year estimates. Each year's estimate in American FactFinder corresponds to the American Community Survey 5-year estimate ending in the same year. Estimates for ZIP Code (ZCTA5) 10314 represent a selected portion of the Freshkills area were available for the period 2012 to 2016. Sex stratified information was not available for most smaller geographic areas.

Prevalence estimates were identified for demographic factors of interest in the former Fresh Kills Landfill study area, Staten Island excluding the former Fresh Kills Landfill study area, and New York City excluding Staten Island. The following demographic factors were considered:

- race (*i.e.*, White, Black or African American, Asian, Middle Eastern or North African, Native Hawaiian or Other Pacific Islander, American Indian, Alaska Native);
- ethnicity (*i.e.*, Hispanic or Latino, not Hispanic of Latino);
- foreign born;
- poverty; and
- college degree.

Table I-2 provides prevalence data for the demographic characteristics listed above among residents of New York City, Staten Island, and a Staten Island ZIP code geographically representative of the former Fresh Kills Landfill study area.

The proportion of White residents in Staten Island and ZCTA5 10314 were appreciably higher than New York City. Staten Island and ZCTA5 10314 had lower proportions Black residents and residents of Hispanic or Latino origin compared to New York City. Staten Island had a smaller proportion of Asian residents compared to New York City, however, ZCTA5 10314 had a proportion of Asian residents more similar to New York City than Staten Island overall. Although the proportion of residents with a bachelor's degree is similar between ZCTA5 10314, Staten Island, and New York City, the overall proportion of residents living below 100% of the Federal Poverty Level was appreciably lower in ZCTA5 10314 and Staten Island compared to New York City. The proportion of foreign born residents is similar between ZCTA5 10314 and Staten Island. Both have fewer foreign born residents compared to all of New York City.

Demographic characteristics in New York City were generally stable. There was a slight decreasing trend in the percentage of White residents. Slight increases were observed citywide in the proportion of foreign-born residents, residents experiencing poverty, and residents obtaining at least a bachelor's degree. The proportion of White residents in Staten Island and ZCTA5 10314 were both higher than in New York City. Staten Island and ZCTA5 10314 had fewer foreign-born residents and residents experiencing poverty compared to all of New York City.

Table I-2. Demographic Characteristics for New York City, Staten Island, and the former Fresh Kills Landfill study area (percent of total population).

Characteristic	Year	NYC[a]	MOE[b]	Staten Island[c]	MOE	ZCTA5 10314[d]	MOE
White	2010	44.2	0.1	75.8	0.3	(-)[e]	(-)
	2011	44.3	0.1	76.0	0.4	(-)	(-)
	2012	44.5	0.1	75.8	0.5	78.5	1.7
	2013	44.3	0.1	75.5	0.4	77.5	1.3
	2014	43.6	0.1	75.5	0.4	77.2	1.4
	2015	43.3	0.1	75.3	0.4	77.3	1.4
	2016	43.1	0.1	75.1	0.4	76.6	1.4
Black or African American	2010	25.2	0.1	10.0	0.2	(-)	(-)
	2011	25.2	0.1	10.2	0.2	(-)	(-)
	2012	25.1	0.1	10.4	0.2	3.6	0.8
	2013	24.9	0.1	10.5	0.2	4.3	0.8
	2014	24.7	0.1	10.5	0.3	4.5	1.0
	2015	24.5	0.1	10.5	0.3	4.7	0.8
	2016	24.4	0.1	10.3	0.3	4.6	0.9
Hispanic or Latino origin	2010	28.2	*[f]	16.3	*	(-)	(-)
	2011	28.4	*	16.8	*	(-)	(-)
	2012	28.6	*	17.2	*	13.2	1.4
	2013	28.7	*	17.4	*	12.4	1.2
	2014	28.8	*	17.7	*	12.5	1.2
	2015	28.9	*	17.8	*	13.7	1.3
	2016	29.0	*	18.0	*	14.3	1.1
Asian	2010	12.6	0.1	7.6	0.1	(-)	(-)
	2011	12.7	0.1	7.8	0.1	(-)	(-)
	2012	12.9	0.1	7.7	0.1	13.7	1.1
	2013	13.0	0.1	7.9	0.1	13.9	1.1
	2014	13.2	0.1	8.0	0.1	14.1	1.0
	2015	13.5	0.1	8.0	0.1	13.7	1.1
	2016	13.7	0.1	8.0	0.1	14.0	1.0
Poverty (Below 100% Federal Poverty Level)	2010	19.1	0.2	10.3	0.6	(-)	(-)
	2011	19.4	0.2	11.0	0.6	(-)	(-)
	2012	19.9	0.2	11.3	0.7	8.2	1.4
	2013	20.3	0.2	11.9	0.7	8.6	1.3
	2014	20.6	0.2	12.3	0.6	7.9	1.1
	2015	20.6	0.2	12.5	0.6	8.6	1.3

	2016	20.3	0.2	12.9	0.6	9.4	1.2
Bachelor's degree (> 25 years of age)	2010	19.8	0.1	17.2	0.6	(-)	(-)
	2011	19.9	0.1	17.4	0.5	(-)	(-)
	2012	20.1	0.1	17.5	0.5	18.4	1.2
	2013	20.4	0.1	17.8	0.5	18.2	1.1
	2014	20.7	0.1	18.6	0.5	18.9	1.2
	2015	21.0	0.1	18.4	0.5	18.3	1.3
	2016	21.3	0.1	18.7	0.5	18.4	1.1
Foreign Born	2010	36.8	0.1	20.8	0.1	(-)	(-)
	2011	36.8	0.1	20.9	0.1	(-)	(-)
	2012	36.9	0.1	20.9	0.1	22.6	0.1
	2013	37.0	0.1	21.2	0.1	22.6	0.1
	2014	37.1	0.1	21.5	0.1	22.8	0.0
	2015	37.2	0.1	21.6	0.1	22.2	0.1
	2016	37.2	0.1	21.9	0.1	23.0	0.1

[a] NYC is New York City
[b] MOE is margin of error
[c] SI is Staten Island
[d] ZCTA5 10314 is the U.S. Census (2010) Zip Code Tabulation Area corresponding to the area of interest in Staten Island, New York
[e] (-) indicates that data were not available for those selected years.
[f] An asterisk indicates that the margin of error column indicates that the estimate is controlled. A statistical test for sampling variability is not appropriate.

I-2. Cancer Risk Factors

The table below provides an overview of risk factors that have been identified for specific cancers of interest in this study. Risk factors have been identified that are associated with genetic or medical conditions, lifestyle or medical treatments, workplace exposures, and environmental exposures. It is important to note that research to identify risk factors associated with specific cancers is ongoing.

Table I-3. Risk Factors for Specific Cancers.

Cancer Site	Genetic/Medical Conditions	Lifestyle/Medical Treatments	Occupational	Environmental
Bladder	Being a man Race/ethnicity: Whites are more likely to develop bladder cancer than African Americans and Latinos; Asian Americans and American Indians have slightly lower rates of bladder cancer Chronic bladder irritation and infections Family history of bladder or other urothelial cancer Bladder birth defects Genetic syndromes, such as Cowden disease	Cigarette smoking Use of the diabetes medicine pioglitazone Use of dietary supplements containing aristolochic acid Not drinking enough fluids Treatment with the chemotherapy drug cyclophosphamide (Cytoxan) Radiation therapy to pelvis	Exposure to aromatic amines, which are sometimes used in the dye industry Industries carrying higher risks include makers of rubber, leather, textiles, and paint products, and printing Workers with increased risk include painters, machinists, hairdressers, and truck drivers (likely due to diesel fumes)	Exposure to arsenic in drinking water
Kidney	Being a man Race/ethnicity: African Americans and American Indians/Alaska Natives have	Cigarette smoking Being overweight or obese Long-term use of phenacetin Use of diuretics	Exposure to cadmium, some herbicides, and organic solvents, particularly trichloroethylene	None identified

Cancer Site	Genetic/Medical Conditions	Lifestyle/Medical Treatments	Occupational	Environmental
	slightly higher rates than whites Family history of kidney cancer High blood pressure Advanced kidney disease Genetic and hereditary conditions, such as von Hippel-Lindau disease			
Thyroid	Being a woman Getting older Genetic and hereditary conditions Family history of thyroid cancer	Diet low in iodine Head or neck radiation therapies in childhood	None identified	Radiation
Non-Hodgkin lymphoma (NHL)	Being a man (but certain types of NHL are more common in women) Race/ethnicity: whites are more likely to develop NHL than African Americans or Asian Americans Family history of NHL Genetic syndromes that impact the immune system	Being overweight or obese Some chemotherapy drugs used to treat other cancers Radiation therapy Use of drugs used to treat rheumatoid arthritis (RA), such as methotrexate and tumor necrosis factor (TNF) inhibitors	Exposure to some herbicides and insecticides, benzene, industrial solvents, vinyl chloride	Radiation

Cancer Site	Genetic/Medical Conditions	Lifestyle/Medical Treatments	Occupational	Environmental
	Reduced immune function Some autoimmune diseases, such as lupus, celiac disease and others Infections that effect the immune system, such as HIV, HTLV-1, HCV	Use of immune-suppressing drugs following organ transplant		
Lung	Lung cancer (both small cell and non-small cell) is the second most common cancer in both men and women; women are more likely to develop lung carcinoid type Race/ethnicity: whites more likely to develop lung carcinoid cancers than African Americans, Asian Americans, or Latinos Previous radiation therapy for other cancers Personal or family history of lung cancer Having an inherited syndrome called multiple endocrine neoplasia type 1 increases risk for carcinoid type	Cigarette smoking Cigar and pipe smoking Radiation therapy to the chest	People who work with asbestos, such as in shipyards and places where insulation is used; Risk is much greater in workers exposed to asbestos who also smoke Workplaces with exposures to radioactive ores, such as uranium; inhaled chemicals such as arsenic, beryllium, cadmium, silica, vinyl chloride; diesel exhaust; radiation, radon	Secondhand smoke Radon Air pollution (especially near heavily trafficked roads)
Breast	Being a woman	Drinking alcohol Being overweight or obese	None identified	Exposure to radiation.

Cancer Site	Genetic/Medical Conditions	Lifestyle/Medical Treatments	Occupational	Environmental
	Certain inherited genes (e.g., BRCA1 or BRCA2) Having a family history of breast cancer Race/ethnicity: white women have a slightly higher risk than African American women; Asian, Latino and Native American women have a lower risk Having dense breast tissue and some benign breast conditions Starting menstruation before age 12 Going through menopause after age 55 Exposure to diethylstilbesterol (DES)	Not being physically active Not having children or first child after age 30 Not breastfeeding Birth control using hormones Combined hormone therapy after menopause		
Total childhood cancer	Acquired mutations to DNA that happen early in a child's life; more rarely, inherited DNA changes	None identified	Not applicable	Radiation Possibly parental exposures to cigarette smoke

Source: American Cancer Society (https://www.cancer.org/)