Sanitation Policies and Public Health Outcomes: What Can be Learned From New York?

Samantha Wiedrich

A Thesis
in the Department of
Economics

Presented in Partial Fulfillment of the Requirements
For the Degree of
Master of Arts (Economics)
at Concordia University
Montréal, Québec, Canada

April 2024

CONCORDIA UNIVERSITY
School of Graduate Studies

This is to certify that the Thesis prepared

By: Samantha Wiedrich

Entitled: Sanitation policies and public health outcomes:
What can be learned from New York?

and submitted in partial fulfillment of the requirements for the degree of

Master of Arts (Economics)

complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by the final Examining Committee:

______________________ Examiner
Dr. Jorgen Hansen

______________________ Supervisor
Dr. Christian Sigouin

Approved by: ______________________
Dr. Christian Sigouin
Graduate Program Director

Date: ____________

____
Dr. Pascale Sicotte, Dean
Faculty of Arts and Science

Abstract

Sanitation Policies and Public Health Outcomes:
What Can be Learned from New York?

Samantha Wiedrich

This paper looks at how the installation of sewers, food hygiene regulations, and trash reform affected mortality from infectious diseases in Brooklyn and Manhattan from 1867 to 1927 combining data from Historical Urban Ecological dataset, the census and Brooklyn and New York Departments of Health. A linear regression with fixed effects is used to investigate which diseases these policy decisions impacted the most. The results will show that milk sanitation, a food hygiene regulation, had the greatest effect on reducing infectious diseases. Installing sewers had a beneficial effect on Manhattan, but Brooklyn saw an increase in infectious diseases as sewage from Manhattan was dumped upstream of Brooklyn. Similarly, trash reform in Manhattan worsened the health of people living in Brooklyn because trash from Manhattan was burned in Brooklyn. These results may guide policy-makers in developing countries to prioritize food safety regulations as well as sanitation of waste over relocation to minimize negative externalities.

Contents

List of Figures

List of Tables

1 Introduction

Research on Low and Middle Income Countries (LMICs) indicates that enhancing access to safe drinking water, sanitation, and hygiene practices could substantially diminish deaths from communicable diseases. The World Health Organization suggests that strategies aimed at addressing these public health issues in 2019 alone could have potentially saved 1.4 million lives worldwide. A lack of sanitation caused 38% of those deaths.[1] This paper seeks to evaluate the significance of public health issues and determine which ones governments should prioritize, drawing insights from historical data from New York City spanning from 1867 to 1927. This approach is relevant because the health environment in New York City during this period bears similarities to that currently observed in LMICs.

New York City initially had open sewers, where raw sewage flowed in the streets, alongside limited trash collection and poor hygiene practices, similar to conditions observed in some LMICs. According to World Health Organization (2019), 15% of the global south has no sewer connections. This means that, while there may be wastewater, there is no sewer hookup to move sewage away from homes. Of the LMICs, 63% of people require fecal sludge management and do not have sewers that treat sewage.[2] These problems are not isolated rural environments. According to research by Satterthwaite, Mitlin, and Bartlett (2015), 27% of the urban population lack basic sanitation in LMICs, and in the poorest countries, that number is as high as 58%. In addition to a lack of sewage, food-born diseases are also prevalent. There is no incentive to invest in food safety along the food supply chain.[3] From the research conducted by Hald et al. (2016), in 2010, 29% of the main causes of diarrhea were from food-borne sources. Hald et al. (2016) extrapolated her data from the World Health Organization (2023a) because measuring the impact of disease due to food quality is difficult because of confounding factors. Trash pickup in LMICs is also underdeveloped due to lack of infrastructure, weak public knowledge, and an absence of guiding policies.[4] According to Caniato, Tudor, and Vaccari (2015), there is an absence of universally agreed upon definitions of waste, and how to remove it, so measuring the impact of trash management is difficult.

1. See World Health Organization (2023a)
2. See Berendes, Sumner, and Brown (2017)
3. See Hoffmann, Moser, and Saak (2019)
4. See Massoud et al. (2021)

Because data in LMICs is sometimes difficult to come by, historic data from other countries can be used to look back at what health measures worked.

New York City provides an opportunity to look at what infrastructure improvements helped the city. In New York City, they faced many disease outbreaks. Initially, diseases were attributed to foul odors, following the miasma hypothesis, but over time, germ theory gained traction, leading to the adoption of public health measures. Over the length of this papers' data collection, open sewers were gradually replaced by closed underground systems, various trash collection initiatives were launched, and food safety policies were introduced. By quantifying the relative efficacy of these measures in preventing deaths from infectious diseases, the paper attempts to draw conclusions on the priority with which they should be implemented nowadays.

Most papers typically assess the effectiveness of health measures without taking into account the sanitation of waste. For example, the research conducted by the World Health Organization (2023a) indicates that improved access to sewers and effective treatment plants could reduce diarrheal deaths, but they lacked access to data to investigate the effectiveness of sewage disposal methods. A study by Dickson-Gomez et al. (2023) showed that while water access, sanitation infrastructure, and hygiene practices were improved in informal settlements in Uganda, improvements in mortality are not as great as expected due to poor fecal sludge disposal. This research was corroborated by Juvakoski et al. (2023) who used municipal level data in Brazil and found that waste management impacted diarrhea prevalence more than water access, sanitation, and hygiene practices. In conclusion, sewer availability, water access, sanitation access, and improved hygiene practices decrease mortality, but mortality seems to depend more on waste management and sewer sanitation than water, sanitation, and hygiene alone.

Food-borne diseases are not studied to the degree that sanitation and sewage are studied because the data is difficult to find. In places with a lack of water, no sewer access, and poor hygiene, the quality of food and its impact is extremely hard to measure because the result of food-borne illnesses is similar to those that exist when there is little health infrastructure.[5] To address this gap, the World Health Organization Food-borne Disease

5. See Grace (2023)

Burden Epidemiology Reference Group used various models to extrapolate the proportion of food-related illnesses from to food-borne diseases, but they do not address milk related diseases.[6] This paper examines the effect of a milk sanitation law on adult mortality to show the impact that food hygiene has on health. There has been some research into dairy production using historical data, but data from LMICs does not exist.

This paper examines this issue by combining data on water and sewage pipes in New York with data on ward level health outcomes. Before New York City had boroughs, the city was split into twenty-five wards in Manhattan and thirty-two wards in Brooklyn.[7] This dataset was created to research health and environmental conditions at the ward level. According to Villarreal et al. (2014), this dataset is the first to digitize the health information from the Health Departments. Most research using city level data uses census related population and death records, but this dataset contains information about deaths from different infectious diseases collected by the Health Department from 1867 to 1927 and relates them to sanitation measures. This means the data on deaths is finer then most other papers because disease specific causes of death are generally unavailable.

This paper considers diarrhea, scarlet fever, diphtheria and croup, typhoid, tuberculosis, whooping cough, as causes of death, as well as child mortality. Most of the research on LMICs considers total deaths, and does not look at deaths due to infectious diseases, or specific types of infectious diseases. Using a food sanitation law, trash pickup reform, and sewer installation, the effect of each policy can be examined to offer more insight into which reduces disease-specific mortality. The effect of sewage pipe installation on ward health has not been investigated using this dataset. To my knowledge, sewage pipe effect on ward health, along with other health-related policies, has not been investigated in New York.

This paper is organized as follows: Section 2 goes over the history of health practices in New York. Section 3 examines literature from studies using historical data. Section 4 briefly explains the data cleaning process and variables creation. Section 5 explains the impact that milk sanitation, trash pickup, and sewers had on diseases. Section 6 concludes. It also offers

6. See Organization et al. (2015)

7. This paper excludes wards twenty-four and twenty-five in Manhattan because they have no sewer data. In Brooklyn, wards one through four, and wards thirty and thirty-one were excluded because they have no sewer data.

policy implications.

2 Historical Context

This section gives historical context to health practices in New York in the 1860s, street sanitation, sewer pipes, and milk laws. New York City has had diseases as long as they have had people. Heaton (1958) chronicles the course of epidemics in New York City dating back to the late 1700s when 2,000 people died from yellow fever and 50,000 fled the city. This yellow fever epidemic continued and there was the first call for a water system and sewage disposal system in 1820. Cholera epidemics then followed in 1832, 1849, and 1873. In 1858, the smallpox epidemic led to the creation of the Board of Health.

In the 1860s, germ theory was being debated in the US (Richmond 1954). Despite not knowing exactly how diseases were transmitted, public health measures were still somewhat effective. For example, Duffy (1968) indicates that when there was an outbreak of a deadly disease, local authorities quarantined people who were sick, burned the clothes of sick people, and fumigated buildings where disease outbreaks took place. He notes that most of the sanitation efforts were directed towards eliminating foul odors because, due to miasma theory, it was believed that bad smells made people sick. As such, there was concern about the foul odor of sewer gas coming from plumbing. People thought that sewer pipes spread diseases.

Because people thought that smells from sewers spread diseases, Duffy (1968) found that by the end of the 1800s, plumbing was the most regulated public health measure. Duffy (1968) explains that after a rise in diarrhea deaths in 1868, the city authorities cracked down on foul odors by sprinkling the streets, gutters, and sewers with chloride, carbolic acid and copperas. It reduced the smell, and incidentally sanitized the streets thus reducing disease and supporting the idea that foul odors made people sick. According to Duffy (1968), because this campaign was so effective, they put these chemicals into sewers, slips and stagnant waters during the following summers. Despite efforts made to sanitize the streets, trash was not picked up.

According to Melosi (1973), there were seven types of trash: garbage (organic waste), rubbish (inorganic waste like paper and cans), human excrement, manure, dead animals, street sweepings, and ashes.[8] Melosi (1973) explains that each type of trash had its own collection system in place. Duffy (1968) recounts that the city paid people called scavengers to pick up trash, but they were allowed to keep the profits of the trash they resold. As a result, the scavengers left the trash that could not be resold behind and picked up the more valuable trash.[9] Oatman-Stanford (2013) indicates that trash pickup effectively started in 1895. Melosi (1973) explains that this trash reform was different then others before because it was created the Department of Street-Cleaning which was led by Colonel George E. Waring, Jr. who was trained in agricultural chemistry.

According to Melosi (1973), Waring first made households separate their trash into bins, eliminated scavengers who kept profits from trash (all profits from trash went towards the city), removed 60,000 abandoned trucks and wagons, then he gave his trash collectors a white uniform to symbolize cleanliness. Melosi (1973) goes on to explain that because Waring wanted the city to be aware of the importance of clean streets, he created a Juvenile Street Cleaning League where children learned about the importance of trash pickup and promote civic pride. According to Melosi (1973), Waring contributed more to reforming trash reform in the US than anyone else.

Duffy (1968) explains that Manhattan had open sewer pipes because they did not reliably have enough water to keep the sewer moving. The sewer system was closed when they increased the water supply. The research of Burrows and Wallace (1998) show that in 1865, the water supply was increased due to the flush toilet coming into vogue. The increase in the water supply meant that there were frequent floods because the open sewers overflowed with the excess water and sewage. Burrows and Wallace (1998) explain that, to reduce frequent floods, the municipal sewer lines were built in Manhattan during the 1860s. Brooklyn followed Manhattan with their sewer pipes installation during the late 1870s.

Burrows and Wallace (1998) discuss how clean milk improved mortality. Before 1862, two thirds of all milk in Manhattan was swill milk and infant mortality was high.[10] Swill milk is milk from cows that are fed liquid byproducts of fermentation. The milk was blue, and so magnesia, chalk, and stale eggs were added so it had the appearance of normal milk. In

8. On the heaviest days, Manhattan collected 1,100 tons of trash according to Melosi (1973).
9. Manure was resold as fertilizer and people threw out worn out items that could be resold.
10. See "Swill-Milk and Infant Mortality" (1858)

1862, swill milk was outlawed, but this law was full of loopholes, and in 1911 milk sanitation was codified. This helped reduce infant mortality and improved the health of New York City by improving the food quality.

In summary, diseases were rampant in Manhattan and Brooklyn. Water related diseases were rampant due to population density, large urban horse and livestock populations, and no effective sewage disposal method. Several policies were introduced as a result. All mortality dropped during this the time due to sewer construction, trash pickup, and swill milk laws. So, these policies seem to have had a positive effect on the health of New Yorkers. However, as all the changes occurred contemporaneously, it is difficult to disentangle the relative contribution of each policy.

3 Literature Review

Around the time of the Industrial Revolution, mortality in cities was higher than rural areas. Woods (2003) analyzes the urban-rural mortality difference during the Industrial Revolution in Japan, China, England and France and finds that the rural urban mortality difference was a continuum. As the size of cities increased, mortality also increased. But, when looking across cultures, it is far harder to effectively compare mortality because health practices and data collection processes are both affected by culture. Haines (2001) investigated the urban rural mortality difference in the US, and his results show that cities had higher levels of mortality than rural areas due to population density, infectious diseases, contaminated water and food, trash, and influxes of immigrants acquiring and contracting diseases. Haines (2001) showed that the urban-rural mortality difference disappeared between 1870 and 1940. By 1940, urban health had surpassed rural health. Research into the urban and rural mortality difference are forced to look at wide areas with uneven data collection methods and are there not able to pull specific results from their research. Despite that, it is important to be aware that urban mortality decreased during the 1860s to 1930s. This paper will focus on a single city with two parts, Manhattan and Brooklyn, which means that the noise from messy variables will be reduced.[11]

11. This entire paragraph should be moved to the historical context section, right?

When using historical data it is often difficult to create a dataset large enough to draw results. In order to create useful datasets, researchers pull data from different cities. Cain and Rotella (2001) used investments into water, sewage and trash to see how the investments in infrastructure affected water-borne diseases. Specifically, they focused on typhoid and diarrhea deaths. Their dataset contains 48 cities with populations over 100,000 between 1899 and 1929 and found that sewage and trash removal infrastructure had the greatest effect on health. However, they focus on the spending on infrastructure, and not real improvements in infrastructure. Cutler and Miller (2005) focus on improvements of water infrastructure, but not sanitation. They investigate the effect of water chlorination and filtration on infant mortality between 1900 and 1936 in 13 U.S. cities. Cutler and Miller (2005) found that sanitizing water supply had a 47% decline in infant mortality.

Gallardo-Albarrán (2020) compares improvements to water and sewage infrastructure in 34 German cities from 1877-1913. They showed that water is good, but it does not have a large effect without adequate sewage. It is intuitive that if one has running water, but dirty water is not removed, water-borne illnesses will still be rampant. Another new intuitive result came from their paper. Gallardo-Albarrán (2020) found that cities with high inequality had smaller health effects from sewage and water. This means that intracity analysis could be more useful than intercity analysis. Since this paper will focus on New York City, variation between wards can be exploited to see the effect of health infrastructure on mortality. This will result in more precise results than focusing on a city as a whole.

Looking at intracity relationships, sewers still seem to be more important for longevity than other health initiatives. Beemer, Anderton, and Leonard (2005) evaluate the difference in mortality between areas with open and closed sewers in Northampton, Massachusetts between 1880 and 1900.[12] They found that industrial areas with open sewers had more deaths than places with closed sewers. But, when sewers were closed, mortality in industrial regions remained the same as before. These results indicate that there could be health risks inherent in the wards that the sewers are unable to mitigate. Alsan and Goldin (2019) also compare water and sewer installation to see which made the biggest impact in mortality in Boston from 1880 to 1920. With their research, they show that clean water and sewage

12. Open sewers are above ground channels that are not covered and designed to carry sewage places.

accounted for approximately to a one third decline in child mortality. Alsan and Goldin (2019) compares the relative effect of clean water with and without sewers, and saw that water has a negative impact on mortality, but water and sewage have a greater decrease in mortality, than water alone.[13]

Kesztenbaum and Rosenthal (2017) compare life expectancy within Paris neighborhoods from 1880-1914 and found that the sewer system increased life expectancy. Like, Beemer, Anderton, and Leonard (2005), Kesztenbaum and Rosenthal (2017) found that the differences within a city are crucial to understanding the effect of sewers on mortality. Because within city variation matters, the present paper will look at variation within the wards of New York. This research is similar to that of Beemer, Anderton, and Leonard (2005), Alsan and Goldin (2019), and Kesztenbaum and Rosenthal (2017), but the dataset that this paper uses spans 60 years whereas theirs spans 40 years at most.

Most of the research on milk laws are focused on infant mortality because milk laws decreased infant mortality by half according to Currier and Widness (2018). The possible reduction in disease in the general population is likely to be paltry compared to cutting deaths in half. As such, there are few or no papers that discuss the impact of milk laws on adults. There is less research on trash reform. According to Melosi (1973), the 1895 trash reform decreased the annual death rate in New York from 26.78 per 1000 in 1882-1894, to 19.63 per 1000 people during the first half of 1897. The research conducted by Melosi (1973) focuses on overall death from infectious diseases, but does not break down which diseases were effected. Besides the research from Melosi (1973), there is scant information about trash pickup and mortality using historical data.

Unlike Woods (2003) who pulled data from different countries, and Haines (2001) who pulled data from the entire U.S., this paper will focus on Manhattan and Brooklyn. Because these are two parts of the same city, the city wide health shocks were the same for both regions. The data collection and environmental factors that impact diseases are the same between the two parts of New York City. This means the noise from different collection techniques, or different geographies, or slightly different policies, will not occur. Gallardo-

13. Sewage infrastructure is put in after water infrastructure because the water is required for the sewage to flow.

Albarrán (2020) found that cities with more inequality had smaller positive benefits from sewage infrastructure. To avoid this problem, this paper is focusing on New York City wards, so that differences between the wards can be exploited to explain the effect of milk laws, trash pickup, and sanitation infrastructure.

This research is closest to that of Beemer, Anderton, and Leonard (2005), Alsan and Goldin (2019), and Kesztenbaum and Rosenthal (2017), but this dataset spans 60 years, whereas their data spans twenty, forty, and thirty-four years, respectively. This dataset includes disease-specific variables, and other historical datasets do not focus on disease-specific variables. In addition to a longer time frame and disease-specific variables, this data includes trash reform and milk sanitation. There is little historical research about the effect of trash reform and milk sanitation on the general population using historical data. This paper is the first to examine the effects of a milk law on the general population. This paper will add to the literature by looking at differences in one city, increasing the data collection period, and including trash reform, milk sanitation, and sewer installation.

4 Data

This section describes the data sources and variable creation. It goes over ward level health sources, then ward level diseases, population data, and sewer pipe data. The ward level disease-specific causes of death was compiled from historical records from 1867 until 1927 by Fogel et al. (2014). This dataset is referred to as the Historical Urban Ecological Data Set (HUE). The ward level information was taken yearly by the Municipal Health Department in Manhattan, and the Department of Health in Brooklyn. This ward level data comprises the cause of death, population, and area of the wards. Because the data was collected over 60 years, most of the variable names changed slightly over time. In addition to spelling changes, at different points in time, there were different levels of specificity in the type of variable. To facilitate the analysis, variables that were relatively similar were grouped together.[14]

The data collection method changed five times throughout the sample.[15] For example,

14. See the Appendix for detailed explanations of the dependent variables.

15. From 1867 to 1879, they collected a set of variables. From 1889 to 1898, a slightly different set of variables were collected. Then, from 1899 to 1914, 1915 to 1925, and 1926 to 1927 the variables collected

from 1867 to 1879, there was no data collected on tuberculosis or child mortality. From 1899 to 1914, there was no data on parturition or rheumatism.[16] To visualize the missing data, Figure 1 shows the average disease mortality divided by the average population for each year. This graph also shows when the health policies were implemented. Tuberculosis is missing for most of the data time span and diarrhea contains the most observations. Because the Health Departments collected different variables at different times, when the variables they collected changed, dummy variables were used to control for this problem, in the hope that the dummy variables would reduce the amount of noise possibly arising from different data collection methods.

The disease variables were compiled from a variety of variables to reduce missing observations and to consolidate information. For example, with diarrhea, for some years there was data on multiple diseases that caused diarrhea, and for other years, there was only diarrhea. [17] Figure 1 shows that Manhattan had a spike in deaths from diarrhea before 1880, and in Brooklyn, the diarrheal deaths remained fairly constant in proportion to the population. Diarrhea is important to this research because it is spread by food or water contaminated with bacteria. Data on typhoid was collected regularly and it is a food and water-borne illness that comes from salmonella bacteria.[18] Both diarrhea and typhoid were food and water-borne illnesses.

The Health Boards also collected data on diseases spread by coughing. There is consistent data on scarlet fever, diphtheria and croup, whooping cough, and tuberculosis. On Figure 1, it can be seen that diphtheria and croup spoke for both Manhattan and Brooklyn before the 1880s. There was a tuberculosis pandemic in Brooklyn according to Fox (1975) around the 1890s and this is likely the cause for the spike in tuberculosis and whooping cough deaths that can be seen on Figure 1. Because both tuberculosis and whooping cough are characterized by their coughing, the two could have been confused for one another, and that could have led to the spike in both diseases that is seen on Figure 1.

changed again.

16. Parturition is when a person dies after giving birth and rheumatism is a fever. These variables were left out of the final paper because for the years they are collected, there is very little data.

17. For a full explanation of the construction of the diarrhea, typhoid, scarlet fever, diphtheria and croup, whooping cough and tuberculosis variables, please see the Appendix where there is a full variable explanation.

18. See World Health Organization (2023b)

In addition to disease-specific variables, the Health Departments collected data on child mortality after 1896 and total deaths in the ward for the entire duration of the dataset. The Health Departments kept data on ward death not due to infectious diseases, as well as infectious disease deaths. So, by adding the ward death from noninfectious and infectious disease, total death was created. Total death does not include child mortality. The disease-specific mortality rate is death from diarrhea, scarlet fever, typhoid, diphtheria and croup, tuberculosis, or whooping cough, divided by the total deaths to create a ratio of deaths from specific causes. The summary statistics for these variables are shown in Table 1. On Table 1, the maximum observation represents the highest proportion of deaths attributed to a specific cause within a ward over the course of a year. Infectious diseases are the total amount of diseases divided by the total amount of death and diseases. The largest proportion of deaths due to tuberculosis was 0.697. This happened in 1898 in Brooklyn during a tuberculosis epidemic. Diarrhea was the second most important source of death. On Table **??**death), the child mortality variable is child mortality divided by total death. This variable is not a ratio, as child mortality is not included in total death. This is why child mortality appears to be 92.9% of all deaths in the table.

The ward disease-specific mortality data is also supplemented with population data from the census. In New York, there was a state census in 1865, 1870, and 1875. There is no census data between 1875 and 1890. In 1885, there were political and bureaucratic issues which stymied the census.[19] There is census data for 1890, but it is unknown if it is from the state census or a police census. In 1890, there was a federal census, but there were reports that it was under counted, so the New York Police recounted.[20] It is unknown if the 1890 data is from the federal or police census because the entire 1890 census was destroyed in 1921.[21] In 1892, there was a state census.[22] There was an 1895 police census indicated in the dataset, but there is minimal corroborating evidence that explains why this census was taken. After that, the dataset uses the federal population from the 1900, 1910, and 1920 censuses. To summarize, in Manhattan, there is population data in 1865, 1870, 1875,

19. See New York Family History (2024)
20. See New York Public Library (2024)
21. See New York Public Library (2019)
22. See New York Family History (2024)

1890, 1892, 1895, 1900, 1910, and 1920. Brooklyn is identical to Manhattan, except for one additional census for 1880 because of the 1880 federal census. The population data was linearly interpolated between adjacent census observations in order to make the ward disease data comparable to each other. This approach effectively assumes that population grew at a constant ate between census years.

To connect pipes to wards, the HUE research team had to determine historic ward boundaries and then determine when streets had sewage pipes installed. To determine historic ward boundaries for Manhattan, they used a collection of ward cards spanning 1817-1913 from the New York City Municipal Archives that were compiled by the staff of the City Register. These records were checked against maps released during the time period.[23] In addition to ward boundaries, they mapped the historic streets because the sewers were placed under the streets. Brooklyn's ward boundaries were more difficult to create. To create the ward maps, data was compiled from a broad collection of historical maps, city ordinances, and laws. These were checked against maps that were periodically released.[24] The timing of ward changes were corroborated by ward reporting from various municipal departments which included references to new and old wards. In order to calculate population density, the area was calculated from these ward boundaries. Once researchers determined the historical ward boundaries, they figured out how sewage pipes lined up with the historic streets.

The sanitation data for Manhattan and Brooklyn comes from the New York Public Library resources as described in Yetter et al. (2015). Manhattan's sanitation data comes from the Board of Aldermen quarterly reports, Croton Aqueduct Department Annual Reports, The Water Purveyor, and the Annual Reports from the Department of Public Works. In Manhattan, most of the water pipes were installed in 1850 and the sewer pipe installation spanned 1797 to 1896 with the average year of installation being 1858. Brooklyn's data comes from the Nassau Water Department Annual Reports, Board of Aldermen, Board of Commissioners, Common Council, and reports from the Mayor of Brooklyn and the Presi-

23. The ward cards were checked against maps at the New York City Department of Records, New York Public Library, the Brooklyn Historical Society, the University of Chicago Map Collection, and the Library of Congress as well as maps available online the David Rumsey Map Collection and ProQuest Sanborn Maps Geo Edition.

24. These were checked against maps from University of Chicago Map Collection as well as maps available online through the New York Public Library, the David Rumsey Map Collection, and ProQuest Sanborn Maps Geo Edition.

dent of Brooklyn. In Brooklyn, most of the water pipes were put in in 1860 and the sewer pipe installation spanned 1863 to 1911 with the average year of sewer installation being 1878. These pipes were geocoded and coded in ArcGIS to create a map of water and sewage networks. In ArcGIS, the ward boundaries and sewage pipes were connected. To see the effect of sewers on ward health, the sewer variable takes the value one after the average year that the ward gets a sewer.

In addition to health and sewer variables, variables for milk sanitation and trash pickup were created. In 1911, a milk sanitation law was passed which codified the swill milk laws for both Manhattan and Brooklyn.[25] The milk law was turned into a dummy variable for all wards in 1911. The trash pickup in Manhattan started in 1895 after many unsuccessful attempts.[26] This is also a dummy variable which takes the value of one after trash reform is implemented for all wards in Manhattan from 1895 onward. In Brooklyn, there were some trash services in 1885 because there is evidence that Brooklyn signed a contract with a trash incinerator company, but trash removal actually started in December 1896 when Brooklyn City Works signed a five year contract for garbage removal with the Brooklyn Sanitary Company.[27] For Brooklyn, the trash dummy is one for 1897 and all years thereafter. The summary statistics of the policy variables are in Table 2. The milk sanitation was in place for 29% of the time from 1867 through 1927. The sewer variable on Table 2 indicates that 94% of the wards had covered sewers by the end of this period. Trash was collected halfway through the time period, so that 50% of observations have trash pickup.

There are more observations in the policy variables than the disease variables because the disease variables have missing observations. The disease data was collected yearly, but some records were lost, so there is missing data.[28] The sewer data has less observations than the milk and trash variables because, for some wards, there were no sewer dates. In Manhattan, wards twenty-four and twenty-five have no sewer data because the ward boundaries, streets, and pipe records were not geocoded. In Brooklyn, wards one through four and wards thirty

25. In 1889, New York City was formed by the agglomeration of Manhattan, Brooklyn, Queens, the Bronx, and Staten Island. See Burrows and Wallace (1998) for an explanation of swill milk and the milk sanitation law.

26. See Melosi (1973)

27. See Juvakoski et al. (2023)

28. For a visual representation of what data is missing, see Figure 1.

and thirty-one have no sewer data. In some cases, data is recorded and there are sometimes zero cases of a disease. When the log of zero is taken, it is undefined.[29] To order for the data to reflect when the policies were working, instead of taking the log of zero, the log of 0.00001 was taken. This allowed the data to show when the health policies were improving the mortality rate.

5 Methodology

Following Cain and Rotella (2001) and Gallardo-Albarrán (2020), this paper will use a linear regression with fixed effects to examine the effect of milk sanitation, sewer construction and trash pickup. As in their research, there is likely unobserved heterogeneity between wards that cannot be explicitly controlled for. This analysis estimates the following model:

$$\log\left(\frac{D_{i,t}}{W_{i,t}}\right) = \alpha_i + \beta_1 M_{i,t} + \beta_2 T_{i,t} + \beta_3 S_{i,t} + \beta_4 \log(\rho_{i,t}) + \beta_5 X_{i,t} + \beta_6 \theta_t + \epsilon_{i,t}, \qquad (1)$$

where $D_{i,t}$ is the number of deaths due to a specific disease for each ward i and each year t, $W_{i,t}$ is the total number of deaths, $M_{i,t}$, $T_{i,t}$, and $S_{i,t}$ are a dummy variables for the milk sanitation law, trash collection reform, and sewer installation, respectively, $\rho_{i,t}$ is the population density, $X_{i,t}$ is a collection of dummy variables to control for the different collection methods, and θ_t is a collection of year dummy variables. This regression will be run for every disease to see the effect that milk sanitation, trash reform, and sewer construction have on specific disease mortality.

The policy variables are milk sanitation, $M_{i,t}$, trash pickup, $T_{i,t}$, and sewer construction, $S_{i,t}$. Sewers, milk sanitation, and trash pickup coefficients should have negative signs because they were implemented to reduce disease. As sewers are put in, infectious diseases should decrease, so there should be a negative effect of sewers on disease. Sewers are expected to reduce diseases that are transmitted by water. Within this dataset, sewers should reduce mortality from diarrhea, and typhoid. After the milk sanitation law was codified, mortality

29. Diarrhea loses 28 observations. Scarlet fever loses 346 observations. Diphtheria and croup lose 75 observations. Tuberculosis loses 2 observations. Whooping cough loses 165 observations. Typhoid loses 315 observations.

should decrease because people are not becoming ill from bad milk. From the research of Currier and Widness (2018), milk laws have been shown to greatly affect infant mortality. In this dataset, it is expected that milk laws will reduce childhood mortality. The data will also show the effect milk sanitation laws had on adult mortality. After trash reform, health should improve because people are not becoming ill from the trash on the streets. According to Melosi (1973), trash reform reduced death. This paper has access to finer data than Melosi (1973), and it is expected that trash reform will reduce diarrhea and all infectious diseases. The magnitude of the policy variables will indicate their respective marginal effect, holding all else constant, of the milk, trash and sewer policies.

The population density, $\rho_{i,t}$, is the linearly interpolated population divided by the area in square feet. This should control for the population density's effect on infectious diseases. The dummy variables, $X_{i,t}$, that control for different collection methods take the value of one, when a certain collection method is used. During the time this data was collected, the Boards of Health recorded slightly different infectious diseases. These dummy variables are intended to account for sample variation in the data that is connected to different collection methods. The dummy variable for year, θ_t, controls for time specific trends in disease that are unrelated to the policy variables. Together, $X_{i,t}$, $\rho_{i,t}$, and θ_t attempt to account for variation in the data that is not due to the policy variables.

Intuitively, population density, $\rho_{i,t}$, should have a positive relationship with infectious disease. This may not be the case because the dependent variable is a ratio of disease-specific death to all death, and the number of deaths is closely related to the population size.[30] There could be a negative relationship between $\rho_{i,t}$ and disease-specific mortality. This is because the disease-specific mortality is divided by total deaths. Total deaths may be a function of population if, for example, normal deaths are a fixed proportion of the population. Population is in the numerator of population density, and death rate, which is a function of population, is in the denominator of the disease-specific mortality. With this relationship, if disease-specific number of deaths remain the same, but total deaths rise because population rose, there could be a negative relationship between disease-specific

30. For places with higher populations, there will be higher amounts of death than places with low populations.

mortality and population density. Likewise, if disease-specific deaths rise, and total death and population remain constant, then there could be a positive relationship between population density and the disease-specific mortality rate.

To interpret the variables, it is important to be aware of the log and level difference. Because the dependent variable is in logs, and the independent variables are level, for each year that a policy was implemented, disease should go down by $100 * \beta_n\%$ where $n \in [2, 5]$. Using logs makes the interpretation more intuitive which is helpful for determining which policies helped the most.

6 Results

This section will discuss results of the milk sanitation law, trash pickup, and sewer implementation. The coefficient estimates for equation (1) are reported in Table 3 through Table 5. The control variables for the change of data collection method used and year dummy variables are not reported. The data collection method variables and year dummy variables are significant for all diseases that are recorded.[31] Table 3 indicates that child mortality decreased after milk sanitation was implemented. The child mortality rate went down 24.1%, ceteris paribus, and is statistically significant at the 95% confidence level. This result is consistent with the research of Currier and Widness (2018).

However, somewhat unexpectedly, after milk sanitation was introduced, it seems that deaths from diarrhea, diphtheria and croup, and typhoid decreased in the adult population. The rate of deaths from diarrhea decreased by 18.1%, ceteris paribus, and is statistically significant at all levels. Improving food quality will reduce intestinal distress, thus reducing diarrheal death.

Holding all else constant, after the milk sanitation law was passed, the diphtheria and croup death rate in adults decreased by 54.8%. The typhoid death rate was reduced by 38.3%, ceteris paribus. These relationships were all statistically significant at the 95% level or higher. Initially, this was unexpected because these are all diseases spread by coughing.

31. The earliest data collection method variable was dropped for child mortality because during that collection period, child mortality was not recorded. Child mortality was only recorded after 1896.

But, upon further research, the connection between milk sanitation and infectious diseases can be explained. According to Dhanashekar, Akkinepalli, and Nellutla (2012) and Steere-Williams (2010), the diseases were carried by dairy workers who accidentally infected the milk. The milk sanitation laws reduced transmission of respiratory illnesses because they eradicated germs from dairy workers.

There are a couple reasons this could have happened. The milk sanitation law could have reduced the deaths in adults due the combined effect of trash and sewer implementation. It could be that the other sources of disease were reduced with sewer and trash implementation, leaving milk consumption as the remaining mode of disease transmission. Another reason could be related to a lack of child mortality data. The child mortality data is not as complete as the adult mortality data, so the adult mortality data could be reacting to the decrease in child mortality. If children are not becoming sick, then they are not contaminating adults, which would lead to a decrease in adult mortality.

In Tables 3, Table 4, and Table 5 there is a general pattern between disease-specific mortality rate and population density when a policy coefficient and population density are both statistically significant. The positive or negative sign on the population density is generally the opposite of the sign on the policy coefficients when population density and the policy coefficients are statistically significant. Holding disease-specific deaths constant, when all deaths decrease, the proportion of death due to a specific disease increases and the population density, if the population has a positive relationship with death, will go down. In other words, when the disease share of death increases, there will be a negative relationship with population density. Equivalently, when the disease share of total deaths decreases, there will be a positive relationship with population density. This is why the policy variables have positive relationships with disease-specific mortality rates when the population density has negative relationships.[32]

It was predicted that trash pickup would reduce deaths. The regression did not show this. In Table 3, most of the diseases have a positive relationship with trash pickup but all are insignificant except tuberculosis. After trash pickup was implemented and sewers were

32. It could be that people moved out of the wards, but there is really no information to draw that conclusion.

installed, tuberculosis deaths increased by 86.6%, ceteris paribus.

The positive relationships could result from endogeneity, or a genuine positive relationship between trash pickup and diseases. There may be an endogenous relationship between trash pickup and diseases because there could be simultaneity. If trash pickup was implemented in reaction to an ongoing epidemic, then there could be simultaneity. Simultaneity would cause a positive statistically significant relationship to appear between disease and trash pickup. In this case, lagged variables would show a negative relationship with disease at some point. This was not the case. Even ten years after trash was picked up, there is still a positive relationship between trash and disease.[33]

There could be a true positive relationship between trash pickup and infectious diseases. A positive relationship could exist because when they picked up the trash, they had to put it somewhere. In Olsen (2015)'s research, it is known that food waste went to Barren Island where it was processed into oil and sludge which went back out into the ocean. Barren Island is on the tip of Brooklyn and is not an island, but a peninsula.[34] Of the nonfood waste, they burned all of it on Brooklyn's Barren Island except ashes and street sweepings. This means that, despite the trash being removed from the streets, it might not have been taken far enough away or disposed of effectively. This could lead to a positive relationship between infectious diseases and trash reform.

To test this, Table 4 and Table 5 report the coefficient estimates when equation (1) is estimated separately for Brooklyn and Manhattan. Because the trash burning happened in Brooklyn, Brooklyn could have more disease related mortality than Manhattan. The regression results do not show this. For Manhattan, trash pickup had a mostly insignificant effect on diseases. Trash pickup and tuberculosis have a positive relationship that is statistically significant. In regions where trash was picked up, tuberculosis went up by 87.2%. This could be due to data collection of tuberculosis which started around when trash was picked up.[35]

In Brooklyn, trash pickup has a largely negative effect on diseases, except for diphtheria

33. Lagged trash has a mostly positive effect on diseases. I tried Manhattan and Brooklyn separately and together with lags of two, five, ten or fifteen years. The lagged variables are either negative and insignificant or positive and statistically significant.

34. Barren Island currently has a Department of Sanitation Training station where people learn to drive dump trucks.

35. See Fox (1975).

and croup, and whooping cough. When trash was picked up after the sewers were installed, diphtheria and croup rose 73.% and 188.9%, respectively, when everything else is held constant. The data shows an increase in whooping cough at the time when trash was picked up, and that could explain the large coefficient. Despite the increases in some diseases, diarrhea, scarlet fever, typhoid, and tuberculosis decreased when trash was picked up and these relationships are statistically significant. The negative relationship with trash pickup and diseases in Brooklyn could be because there was less infrastructure in Brooklyn when trash was picked up. Brooklyn developed slower than Manhattan, and experienced a surge in population around the 1880s, before trash pickup was implemented.[36] Then, Brooklyn joined Manhattan in 1898, and access to infrastructure improved because trash pickup was centralized. So, the relative impact of trash pickup on Brooklyn was greater than it was on Manhattan because there was less infrastructure in Brooklyn then there was in Manhattan when trash was picked up.

It was predicted that sewers would decrease disease, so there should be a negative correlation between sewers and disease-specific mortality. This was not quite the case. As shown in Table 3, diarrhea has a positive statistically significant relationship with sewers. Child mortality shows a negative relationship with sewers, but this estimate may be biased upward due to child mortality not being a true ratio of child mortality to total death.[37] This result was unexpected, but upon further reflection, can be explained.

This could be due to a lack of variation in the data, or a true positive relationship. As can be seen on Figure 1, in Manhattan, most of the sewers were installed before the Health Department existed, so there is less data collected before Manhattan had sewers installed. Brooklyn, who had sewers installed after Manhattan, had more variation in when sewers were installed, and there was more data collected before the sewers were installed. The results could be picking this ambiguity.

By splitting the data and regressing Manhattan and Brooklyn separately, this can be investigated. In Table 4 and Table 5 the results can be seen. Table 4 shows that in Manhat-

36. See Burrows and Wallace (1998).

37. Briefly, child mortality is divided by all infectious disease deaths added to all deaths from other causes. This means the child mortality values are larger than they should be. For more information, see the Data Section.

tan, the implementation of the sewer has a mostly negative, but not statistically significant, effect on infectious diseases. The lack of statistically significant results indicates that the data is not very good at showing the impact of sewers. On Table 5, sewers are shown to have a positive relationship with all diseases. Notably, tuberculosis has a positive and statistically significant relationship with sewer implementation. After sewers are implemented, tuberculosis increases by 59.6%, ceteris paribus. This could explain be due to a true positive relationship between sewers and health. The sewers put untreated human waste into the river between Manhattan and Brooklyn. This means, Manhattan was effectively removing human waste and pushing it over to Brooklyn which lies downstream of Manhattan.

This result makes sense because fecal sludge was sent out into the water around Manhattan, and flowed downstream to Brooklyn. So, the sewers reduced infectious diseases in Manhattan, while increasing infectious diseases in Brooklyn. The sewers increase the chance of becoming sick because the sewage was not treated. Research by the World Health Organization (2023a) says that untreated sewage could lead to problems like this. This conclusion, that untreated sewage in water is causing illness is also found by Dickson-Gomez et al. (2023) and Juvakoski et al. (2023).

In conclusion, milk sanitation decreased deaths, but trash and sewer had more ambiguous effects. Milk sanitation that was implemented after trash reform and sewer installation, had a negative effect on mortality. Trash removal reduced mortality in Brooklyn, but had an ambiguous effect on Manhattan. This is probably because there was less infrastructure in Brooklyn when the trash was picked up then Manhattan.[38] Sewers reduced mortality from infectious diseases in Manhattan, but raised the mortality from infectious diseases in Brooklyn because raw sewage was pumped out of Manhattan into the river upstream from Brooklyn.

7 Conclusion

This paper investigated the impact of sewers, trash pickup and milk sanitation on health using a linear regression with fixed effects. This regression was used because, like Cain and

38. See Burrows and Wallace (1998)

Rotella (2001) and Gallardo-Albarrán (2020), there are time invariant differences between wards that can be controlled for using fixed effects. Control variables were data collection changes, population density of the wards and dummy variables for the years. It was expected that milk, trash and sewers would lower mortality from infectious diseases. After the sewer was installed and trash was picked up, milk sanitation decreased mortality from diarrhea, diphtheria and croup, typhoid, and child mortality. Milk sanitation reduced diphtheria and croup and typhoid because it prevented the germs from dairy laborers from infecting the milk. Trash and sewer implementation did not universally decrease mortality from infectious diseases. After sewers were implemented, trash reform decreased mortality on Brooklyn. Trash reform does not seem to have improved infectious disease mortality in Manhattan. Moving the sewage out of Manhattan decreased mortality from infectious diseases for the Manhattan residents. However, as raw sewage was put into the river, this seems to have led to increased mortality due to diphtheria and croup and tuberculosis for Brooklyn residents. When Manhattan implemented their policies, they did not take into account the effect it would have on Brooklyn. There could have been a different outcome if both cities coordinated their efforts.

These results are not surprising, but they are not as intuitive as expected. This research lines up with research from developing countries more than research using historical data. Research using historical data, like Alsan and Goldin (2019), Kesztenbaum and Rosenthal (2017) and Gallardo-Albarrán (2020), find that sewage decreases mortality. Cain and Rotella (2001) found that sewage and trash pickup decreased mortality. These results show that sewers reduced mortality in Manhattan, but they increased mortality in Brooklyn. Historical research is often myopic in scope and is generally unable to see negative externalities like this.

A caveat with this research is that because the milk sanitation, trash reform, and sewer installation were installed sequentially, the impact of milk is predicated on the impact of trash reform and sewer installation. Similarly, the impact of trash reform is predicated on the impact of the sewers. This means that the effect of one policy is difficult to completely extricate from the impact of the preceding policies. Nevertheless, the results highlight the importance of health reforms and their impact on mortality.

The conclusions drawn here line up more with research in LMICs. Dickson-Gomez et al. (2023) and Juvakoski et al. (2023) both found that sewers were useful, but if sewage was not being treated, the health improvements were not significant. The research by Alsan and Goldin (2019), Kesztenbaum and Rosenthal (2017), Gallardo-Albarrán (2020), and Gallardo-Albarrán (2020) only examined one city, which means they did not look at where the sewage was going. This research showed that sewers and trash require sanitation, otherwise they just move diseases around. Showing the impact of milk on diseases was invaluable. Currier and Widness (2018) showed that milk laws decreased infant mortality by half, but there was no research on milk laws' effects on the general population. This research is important because it highlights the substantial impact that food sanitation laws may have on mortality.

The results suggest that, going forward, policy efforts should be focused on food sanitation, trash and sewage sanitation. Milk sanitation, after trash was picked up and sewers were installed, reduced more deaths than was expected. Food sanitation guidelines may be easier to implement than infrastructure reform. The trash reform, after sewers were installed, also reduced mortality in Brooklyn where there was less infrastructure. By focusing on areas where there is less infrastructure, every bit of sanitation infrastructure can improve the health of the residents. The negative externalities in waste management should be taken into consideration in order to prevent unintentional deaths. It is important to clean up cities, but also to take into account what happens to their neighbors.

References

Alsan, Marcella, and Claudia Goldin. 2019. "Watersheds in child mortality: The role of effective water and sewerage infrastructure, 1880–1920." *Journal of Political Economy* 127 (2): 586–638.

Beemer, Jeffrey K, Douglas L Anderton, and Susan Hautaniemi Leonard. 2005. "Sewers in the city: A case study of individual-level mortality and public health initiatives in Northampton, Massachusetts, at the turn of the century." *Journal of the history of medicine and allied sciences* 60 (1): 42–72.

Berendes, David M, Trent A Sumner, and Joe M Brown. 2017. "Safely managed sanitation for all means fecal sludge management for at least 1.8 billion people in low and middle income countries." *Environmental science & technology* 51 (5): 3074–3083.

Burrows, Edwin G, and Mike Wallace. 1998. *Gotham: a history of New York City to 1898.* Oxford University Press.

Cain, Louis P, and Elyce J Rotella. 2001. "Death and spending: Urban mortality and municipal expenditure on sanitation." In *Annales de démographie historique,* 139–154. 1. Cairn/Softwin.

Caniato, Marco, T Tudor, and Mentore Vaccari. 2015. "International governance structures for health-care waste management: A systematic review of scientific literature." *Journal of environmental management* 153:93–107.

Currier, Russell W, and John A Widness. 2018. "A brief history of milk hygiene and its impact on infant mortality from 1875 to 1925 and implications for today: a review." *Journal of food protection* 81 (10): 1713–1722.

Cutler, David, and Grant Miller. 2005. "The role of public health improvements in health advances: the twentieth-century United States." *Demography* 42 (1): 1–22.

Dhanashekar, Revathi, Sindhura Akkinepalli, and Arvind Nellutla. 2012. "Milk-borne infections. An analysis of their potential effect on the milk industry." *Germs* 2 (3): 101.

Dickson-Gomez, Julia, Agnes Nyabigambo, Abigail Rudd, Julius Ssentongo, Arthur Kiconco, and Roy William Mayega. 2023. “Water, sanitation, and hygiene challenges in informal settlements in Kampala, Uganda: a qualitative study.” *International Journal of Environmental Research and Public Health* 20 (12): 6181.

Duffy, John. 1968. *History of Public Health in New York City, 1625-1866: Volume 1.* Vol. 1. Russell Sage Foundation.

Encyclopedia Britannica. 2024. “Scrofula.” Accessed on: March 22, 2024. https://www.britannica.com/science/scrofula.

Fogel, Robert W, Dora L Costa, Carlos Villarreal, Brian Bettenhausen, Eric Hanss, Christopher Roudiez, Noelle Yetter, and Andrea Zemp. 2014. *Union Army Data - Historical Urban Ecololgical (HUE).* https://doi.org/DOIoftheDataset(ifavailable).

Fox, Daniel M. 1975. “Social policy and city politics: tuberculosis reporting in New York, 1889-1900.” *Bulletin of the History of Medicine* 49 (2): 169–195.

Gallardo-Albarrán, Daniel. 2020. “Sanitary infrastructures and the decline of mortality in Germany, 1877–1913.” *The Economic History Review* 73 (3): 730–757.

Grace, Delia. 2023. “Burden of foodborne disease in low-income and middle-income countries and opportunities for scaling food safety interventions.” *Food Security* 15 (6): 1475–1488.

Haines, Michael R. 2001. “The urban mortality transition in the united states, 1800-1940* voici u, n test.” In *Annales de démographie historique,* 33–64. 1. Cairn/Softwin.

Hald, Tine, Willy Aspinall, Brecht Devleesschauwer, Roger Cooke, Tim Corrigan, Arie H Havelaar, Herman J Gibb, Paul R Torgerson, Martyn D Kirk, Fred J Angulo, et al. 2016. “World Health Organization estimates of the relative contributions of food to the burden of disease due to selected foodborne hazards: a structured expert elicitation.” *PloS one* 11 (1): e0145839.

Heaton, Claude E. 1958. “Three hundred years of medicine in New York City.” *Bulletin of the History of Medicine* 32 (6): 517–530.

Hoffmann, Vivian, Christine Moser, and Alexander Saak. 2019. "Food safety in low and middle-income countries: The evidence through an economic lens." *World Development* 123:104611.

Hollis, LW. 1895. "Diphtheria and Membranous Croup." *Texas Medical Journal* 10 (8): 394.

Juvakoski, Anni, Henrik Rantanen, Michela Mulas, Francesco Corona, Riku Vahala, Olli Varis, and Ilkka Mellin. 2023. "Evidence of waste management impacting severe diarrhea prevalence more than WASH: An exhaustive analysis with Brazilian municipal-level data." *Water Research* 247:120805.

Kesztenbaum, Lionel, and Jean-Laurent Rosenthal. 2017. "Sewers' diffusion and the decline of mortality: The case of Paris, 1880–1914." *Journal of Urban Economics* 98:174–186.

Massoud, May, George Lameh, Marco Bardus, and Ibrahim Alameddine. 2021. "Determinants of waste management practices and willingness to pay for improving waste services in a low-middle income country." *Environmental management* 68 (2): 198–209.

Mayo Clinic. 2024. "Scarlet Fever: Symptoms & Causes." Accessed on: March 22, 2024. https://www.mayoclinic.org/diseases-conditions/scarlet-fever/symptoms-causes/syc-20377406.

Melosi, Martin V. 1973. ""Out of Sight, Out of Mind" The Environment and Disposal of Municipal Refuse, 1860–1920." *The Historian* 35 (4): 621–640.

Merriam-Webster. 2024a. "Definition of Consumption." Accessed on: March 22, 2024. https://www.merriam-webster.com/dictionary/consumption.

———. 2024b. "Definition of Phthisis." Accessed on: March 22, 2024. https://www.merriam-webster.com/dictionary/phthisis.

———. 2024c. "Definition of Scarlatina." Accessed on: March 22, 2024. https://www.merriam-webster.com/dictionary/scarlatina.

National Library of Medicine. 2022. "MedGen: Enterocolitis." Accessed on: March 22, 2024. https://www.ncbi.nlm.nih.gov/medgen/4966.

New York Family History. 2024. "New York State Census Records Online." Accessed on: March 22, 2024. https://www.newyorkfamilyhistory.org/subject-guide/new-york-state-census-records-online.

New York Public Library. 2024. "New York Public Library Genealogy Guide: New York State Censuses." Accessed on: March 22, 2024. https://libguides.nypl.org/c.php?g=885769&p=6409529.

———. 2019. "The 1890 New York City Police Census: What It Is and How to Use It." Accessed on: Date you accessed the website. https://www.nypl.org/blog/2019/05/09/1890-new-york-city-police-census.

NHS. 2020. "Dysentery." Accessed on: March 22, 2024. https://www.nhs.uk/conditions/dysentery/.

Oatman-Stanford, Hunter. 2013. "A filthy history: When New Yorkers lived knee-deep in trash." *Collectors weekly* 24.

Olsen, Kevin. 2015. "What Do You Do With the Garbage? New York City's Progressive Era Sanitary Reforms and Their Impact on the Waste Management Infrastructure in Jamaica Bay." *Long Island History Journal* 24 (1): 1–29.

Organization, World Health, et al. 2015. *WHO estimates of the global burden of foodborne diseases: foodborne disease burden epidemiology reference group 2007-2015.* World Health Organization.

Richmond, Phyllis Allen. 1954. "American attitudes toward the germ theory of disease (1860-1880)." *Journal of the history of medicine and allied sciences,* 428–454.

Rousseau, George S, and David Boyd Haycock. 2003. "Coleridge's choleras: Cholera morbus, asiatic cholera, and dysentery in early nineteenth-century england." *Bulletin of the History of Medicine,* 298–331.

Satterthwaite, David, Diana Mitlin, and Sheridan Bartlett. 2015. *Is it possible to reach low-income urban dwellers with good-quality sanitation?,* 1.

Steere-Williams, Jacob. 2010. “The perfect food and the filth disease: milk-borne typhoid and epidemiological practice in late Victorian Britain.” *Journal of the History of Medicine and Allied Sciences* 65 (4): 514–545.

“Swill-Milk and Infant Mortality.” 1858. *The New York Times.*

Villarreal, Carlos, Brian Bettenhausen, Eric Hanss, and Jonathan Hersh. 2014. “Historical health conditions in major US cities: The HUE data set.” *Historical Methods: A Journal of Quantitative and Interdisciplinary History* 47 (2): 67–80.

Woods, Robert. 2003. “Urban-rural mortality differentials: an unresolved debate.” *Population and development review* 29 (1): 29–46.

World Health Organization. 2023a. *Burden of disease attributable to unsafe drinking-water, sanitation and hygiene.* World Health Organization.

———. 2019. *Progress on household drinking water, sanitation and hygiene 2000-2017: special focus on inequalities.* World Health Organization.

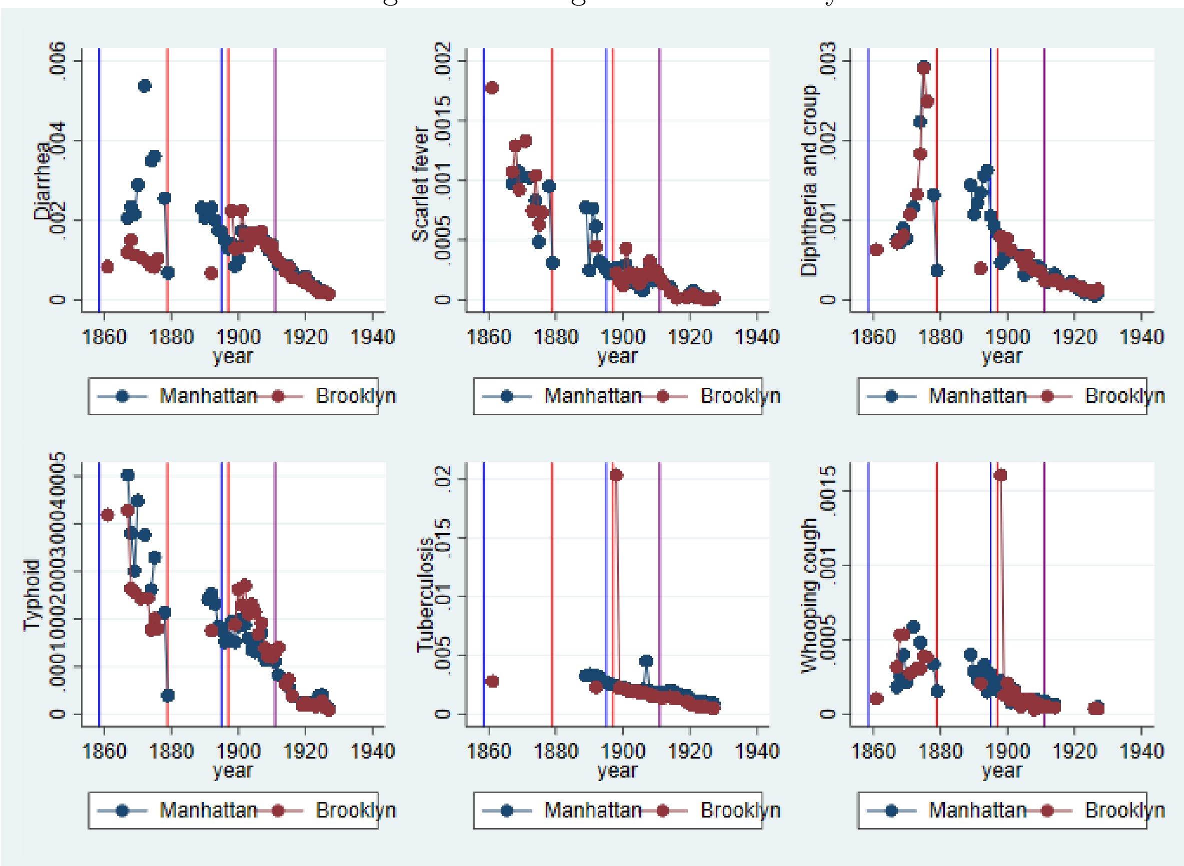
———. 2023b. “Typhoid Fever.” Accessed on: March 22, 2024. https://www.who.int/newsroom/fact-sheets/detail/typhoid#:~:text=Typhoid%20fever%20is%20a%20life,through%20contaminated%20food%20or%20water..

Yetter, Noelle, Eric Hanss, Carlos Villarreal, Brian Bettenhausen, Jonathan Hersh, and Andrea Zemp. 2015. *Data User’s Manual: Historical Urban Ecological Data Set.* The National Bureau of Economic Research.

9 Appendix

9.1 Figures

Figure 1: Average disease mortality



Note: This graph shows the data collected for each disease for Manhattan and Brooklyn. The y-axis shows the yearly total deaths from disease divided by the linearly interpolated population for that year. The x-axis shows the year the data was collected. The first blue line shows the average year that sewers were installed in Manhattan. The first red line shows the average year that sewers were installed in Brooklyn. The second blue and red line shows when trash pickup started in Manhattan and Brooklyn respectively. The purple line indicates when the milk law was passed. When the milk law was passed, Brooklyn and Manhattan and merged and were part of New York City. There was a tuberculosis pandemic in Brooklyn according to Fox (1975) around the 1890s and this is likely the cause for the spike in tuberculosis and whooping cough deaths

9.2 Tables

Table 1: Disease-specific mortality rate

Variable	Mean	Min	Max	Obs.
Diarrhea	.047	0	.292	1,869
Scarlet fever	.010	0	.078	1,869
Typhoid	.005	0	.040	1,825
Diphtheria and croup	.021	0	.134	1,773
Tuberculosis	.090	0	.697	1,533
Whooping cough	.007	0	.079	1,437
Child mortality	.216	0	.903	1,281

Note: The variables have different numbers of observations because of different collection methods which counted slightly different diseases, and there are not Health Department records for every year. The mean is the sample mean and not the mean by wards.

Table 2: Policy variables

Variable	Mean	Obs
Sewer	.94	3,299
Milk	.29	3,299
Trash	.51	3,299

Note: This table shows the summary statistics for the policy variables. 94% of wards had covered sewers by the end of the sample. Trash was picked up for 51% of the sample. For 29% of the sample, milk was sanitized.

Table 3: Coefficient estimates for various dependent variables

	Coefficients				
Dependent variables	Milk	Trash	Sewer	Density	Obs.
Diarrhea	-.181*	.321	.213	.097	1,868
	(.080)	(.258)	(.155)	(.053)	
Scarlet fever	-.176	-.999	.033	.538**	1,868
	(.159)	(.514)	(.308)	(.105)	
Diphtheria and croup	-.548**	.093	-.360	.715**	1,772
	(.108)	(.446)	(.207)	(.070)	
Typhoid	-.383*	.637	.202	.515**	1,824
	(.160)	(.519)	(.311)	(.106)	
Tuberculosis	.020	.866**	.390	-.137**	1,532
	(.043)	(.138)	(.258)	(.039)	
Whooping cough	-.265	-.324	-.092	.243*	1,436
	(.134)	(.431)	(.268)	(.106)	
Child mortality	-.241**	0	-.600*	.511**	1,280
	(.050)	(omitted)	(.300)	(.059)	

Note: These coefficients are from a linear regression with fixed effects. The control variables are not shown. The control variables for change of data collection method were always statistically significant if the dependent variable was collected during that time period. The trash pickup variable was omitted for the regression when child mortality was the dependant coefficient because of collinearity. There is collinearity because child mortality was only collected after 1896, which is when trash pickup started. Standard errors are within parentheses. Significance levels are denoted as: * $p < 0.05$, ** $p < 0.01$.

Table 4: Manhattan coefficient estimates for various dependent variables

	Coefficients				
Dependent variables	Milk	Trash	Sewer	Density	Obs.
Diarrhea	-.039	-.210	-1.242	.181	978
	(.148)	(.324)	(.823)	(.095)	
Scarlet fever	.068	-.092	-.278	.756**	978
	(.225)	(.491)	(1.246)	(.143)	
Diphtheria and croup	-.564**	.573	-1.173	1.069**	934
	(.185)	(.398)	(1.011)	(.117)	
Typhoid	-.403	.522	-1.749	.585**	934
	(.226)	(.496)	(1.261)	(.146)	
Tuberculosis	-.036	.872**	0	.113*	791
	(.060)	(.132)	(omitted)	(.052)	
Whooping cough	.125	-.359	.583	.510**	780
	(.183)	(.401)	(1.027)	(.142)	
Child mortality	-.147	0	0	1.008**	615
	(.097)	(omitted)	(omitted)	(.127)	

Note: These coefficients use data from Manhattan from a linear regression with fixed effects. The control variables are not shown. The control variables for different collection forms were always statistically significant if the dependent variable was collected during that time period. Variables whose coefficients are zero were omitted because of collinearity. Standard errors are within parentheses. Significance levels are denoted as: * $p < 0.05$, ** $p < 0.01$.

Table 5: Brooklyn coefficient estimates for various dependent variables

	Coefficients				
Dependent variables	Milk	Trash	Sewer	Density	Obs.
Diarrhea	-.242**	-.368*	.162	-.214**	890
	(.056)	(.122)	(.088)	(.088)	
Scarlet fever	-.389	-4.682**	.298	.592**	890
	(.228)	(.500)	(.359)	(.189)	
Diphtheria and croup	-.404**	.734**	.119	.017	838
	(.109)	(.237)	(.170)	(.089)	
Typhoid	-.347	-3.534**	.621	.414*	890
	(.209)	(.457)	(.328)	(.173)	
Tuberculosis	.118*	-.680**	.596**	-.374**	741
	(.051)	(.113)	(.227)	(.064)	
Whooping cough	-.523**	1.889**	.181	-.029	656
	(.192)	(.423)	(.312)	(.182)	
Child mortality	-.197**	0	-.061	-.103**	665
	(.027)	(omitted)	(.118)	(.038)	

Note: These coefficients use data from Brooklyn from a linear regression with fixed effects. The control variables are not shown. The control variables for different collection forms were always statistically significant if the dependent variable was collected during that time period. Variables whose coefficients are zero were omitted because of collinearity. Standard errors are within parentheses. Significance levels are denoted as: * $p < 0.05$, ** $p < 0.01$.

9.3 Variable explanation

Diarrhea

Diarrhea was compiled from 18 variables: spelling variations of diarrhea, cholera morbus, dysentery, inflammation of the bowls, and enterocolitis. This is partly due to yearly spelling changes in the word diarrhea, and partly due to the level of specificity. There are a variety of ways to die from diarrhea, and in some years, some wards recorded more ways than others. For example, cholera morbus is an old term that refers to acute gastroenteritis that is characterized by severe cramps, diarrhea, and vomiting.[39] Because cholera morbus was characterized by diarreah, it was included in the diarrhea variable. Similarly, dysentery involves stomach cramps and diarrhea.[40] Inflammation of the bowels and enterocolitis are also characterized by diarrhea.[41] Diarrhea, cholera morbus, dysentery, inflammation of the bowels, and enterocolitis were not available for the entire duration of the dataset, but when combined to form the diarrhea variable, there remained some missing observations.

Typhoid

Typhoid was fairly consistent throughout the data collection period and was created from typhoid fever and fever typhoid.

Scarlet fever

The scarlet fever variable was compiled from three variables. Two were variations of the words scarlet fever, and the third was scarlatina which is another name for scarlet fever.[42] Scarlet fever is a bacterial illness that creates a bright red rash on the body and is spread by coughing.[43]

Diphtheria and croup

In layman's terms, in the 1880s, diphtheria was the illness causing white patches in the throat, and croup was the barking cough caused by the illness.[44] The diphtheria and croup

39. See Rousseau and Haycock (2003)
40. See NHS (2020)
41. See National Library of Medicine (2022)
42. See Merriam-Webster (2024c)
43. See Mayo Clinic (2024)
44. Now, diphtheria and croup are separated by their bacterial origin. See Hollis (1895) for an explanation of how diphtheria and croup were categorized during the late 1800s.

variable is created from two diphtheria variables, a croup variable, two diphtheria and croup variables and a membranous croup variable. Membranous croup is the longer name for croup.

Whooping cough

The whooping cough variable is compiled from two variables that are both different spellings of ‘whooping cough’.

Tuberculosis

Tuberculosis is spread by coughing as well, and the variable tuberculosis was created from phthisis, consumption, scrofula, and other variables with name variants of tuberculosis: ‘tuberculosis pulmonalis’, ‘pulmonary tuberculosis’, and ‘other tuberculosis diseases’. Phthisis and consumption are the same as tuberculosis.[45] Scrofula is the name for tuberculosis bacteria infecting the lymph nodes of the neck, but was historically interchangeable with tuberculosis.[46]

45. See Merriam-Webster (2024b) and Merriam-Webster (2024a)
46. See Encyclopedia Britannica (2024)