Woburn
A Legacy of Waste

Contamination in Our Communities: A Case Study of Woburn, Massachusetts

Welcome!

This case study focuses on a childhood cancer cluster in Woburn, Massachusetts, a town 13 miles northwest of Boston. Between 1969 and 1986, twenty-one Woburn children were diagnosed with leukemia, and twelve died. Anne Anderson, the mother of one of these children, was the first to notice that too many children in her neighborhood were being diagnosed with leukemia. Since then, hazardous chemicals dumped by local industry, which subsequently contaminated the drinking water supply, have been linked with the excess incidences of cancer.

Throughout this case study, we will use Woburn as an example to illustrate how to find environmental and health data, and explain how rates of disease can be calculated to help answer the question: 'Is this community experiencing unusual health problems?'

Learning Objectives:

After completing this case study the student will be able to:

- Identify and describe resources available to collect environmental and health data on a community.
- Describe the properties and major sources of volatile organic compounds, such as TCE, and predict how they behave in environmental media.
- Collect current data on the toxicity of a xenobiotic.
- Outline pathways for human exposure to environmental health hazards in Woburn.
- Estimate the burden and patterns of disease in communities in order to prioritize health needs.
- Calculate the SIR (Standardized Incidence Ratio) and SMR (Standardized Mortality Ratio) and interpret the results to determine whether a community is experiencing an unusually high rate of a disease.
- Describe the origins of the Superfund law and analyze the challenges faced when implementing the law to clean up the nation's hazardous waste sites.

Woburn - Early History

Woburn was established as a settlement in the early 1640s. For many years it was primarily an agricultural community, but the first tanning enterprise began in 1648, and Gershom Flagg built a house and tannery next to the Town Meeting Hall in 1668. Shoe making shops began to appear in the late 1600s, and more small tanneries appeared, although agriculture was the foundation of the economy until the 1800s. Industry gradually grew, largely because of the abundant water supply and transportation afforded by the Aberjona River and the Middlesex Canal, which opened in 1803 (depicted on the right; image source: http://library.uml.edu/clh/MidCan.html). Development was also boosted by opening of the Boston & Lowell Railroad in 1835 and the Woburn Loop of the railroad in 1844. Woburn's proximity to Boston and the ability to transport materials and goods via the waterways and railroad enabled the tanning, shoemaking, and other industries to thrive in the 1800s. The demand for shoes and boots during the Civil War provided yet another boost to the economy of the region. Shoe making was the principal industry in Woburn for many years, but eventually leather production eclipsed the shoe making industry. Tanneries were so central to the the economy of Woburn that the Woburn High School mascot became the "Tanner."

The "Tanners" (audio file)

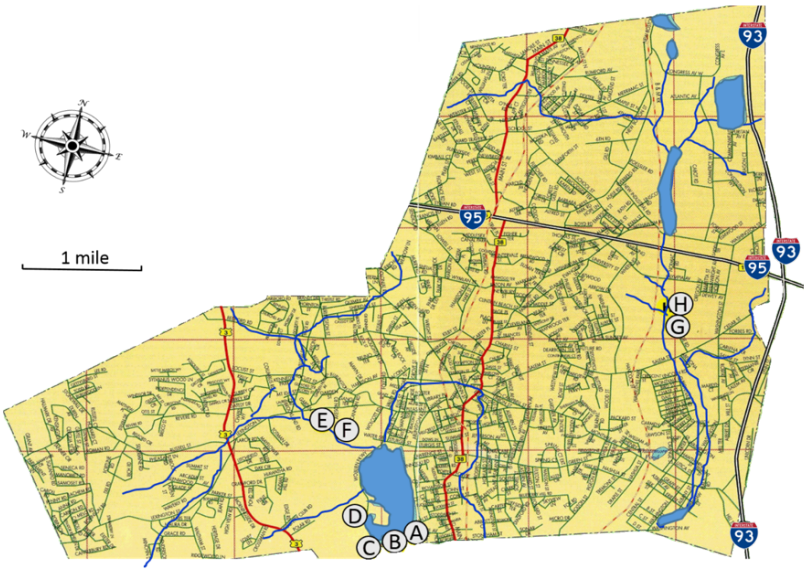
The History of Pollution in Woburn, MA

In 1853 Robert Eaton founded Woburn Chemical Works in the vicinity of what is now known as the Woburn Industri-Plex in northeastern Woburn; the company supplied chemicals needed in local tanneries, textile mills, and the leather and paper industries. The company was later acquired by the Merrimac Chemical Company, which in turn was purchased by the Monsanto Chemical Company in 1929. In 1934 the property was sold to the New England Chemical Company, which was later purchased by Consolidated Chemical Company and then to the Stauffer Chemical Company, which remained in operation until 1969.

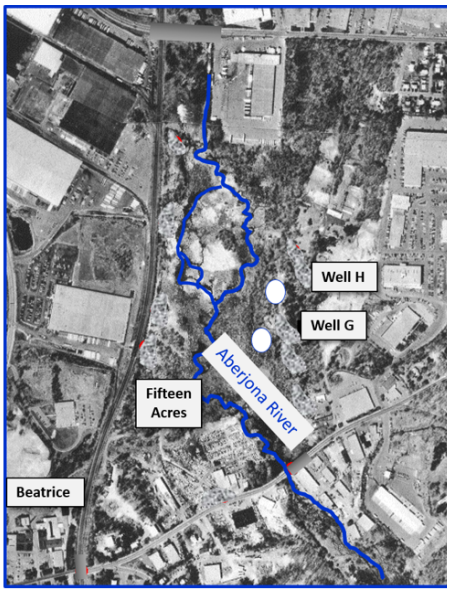
For over a hundred years companies in this area of Woburn manufactured a wide variety of chemicals, including lead-arsenic insecticides, acetic acid, sulfuric acid, hydrochloric acid, phenol, benzene, toluene, and explosives. Glue was also manufactured from raw animal hide and chrome-tanned hide wastes. Wastes generated from manufacturing were often dumped into swamps or depressions. Ultimately, the area became designated the Industri-Plex Superfund Site. For a detailed history of the industrial development in Woburn, see the document below, written by Joel A. Tarr, PhD, a Professor of History and Public Policy at Carnegie Mellon University. Dr. Tarr was a consultant to W. R. Grace.

The Woburn Water Supply

Up until the 1960s Woburn's water was supplied from six wells in the vicinity of Horn Pond (wells A-F on the map below on the left). As the population grew, more water was needed; Well G was put into operation in 1964, and Well H was added in 1967. Wells G and H were located in east Woburn in the vicinity of the Aberjona River, shown in greater detail in the aerial photograph on the right. Long ago the Aberjona River had been a large river that ran through a valley that had been formed by glaciers. Slowly, over many years, the valley gradually filled with sand, gravel, and silt; the Aberjona River was slowly reduced to a meandering stream, but the ancient valley below, which was now filled with gravel and porous dirt, had become an underground water reservoir. At the surface there were now marshlands, swamps, and wetlands. Unfortunately, much of the industrial activity was located in this area as well, including the W.R. Grace Cryovac Division, Unifirst (a uniform dry cleaning company), and the Riley Tannery, which was purchased by Beatrice Foods in 1978. The "Fifteen Acres" shown on the aerial photographe was a parcel of land purchased by the Riley tannery in 1951; during the 1950 s and 1960s this plot of land was used used to dump waste from the tannery, including chemicals such as tricholoethylene (TCE) .



Adapted from http://serc.carleton.edu/woburn/resources/Woburn_mapes.html



Adapted from http://classes.colgate.edu/dkeller/geo

A more detailed account of Woburn's water supply system, including its evolution over time can be found here.

1970s: Cancer in Woburn

Anne Anderson and her husband Charles moved to Woburn in 1965. They bought a house in east Woburn where the Aberjona River, really no more than a stream, wound through marshes and what had been farms and orchards. But their lives were changed forever when their son Jimmy was diagnosed with acute lymphocytic leukemia (ALL) in January 1972; Jimmy was 3½ years old. Jimmy began treatments in Boston, and when he returned solicitous neighbors stopped by offering to help Anne. During conversations with neighbors, Anne learned that there were two other children who had been diagnosed with leukemia just a few blocks away. This struck Anne as unusual. The doctor treating Jimmy for leukemia said that the cause of ALL was unknown, but one theory was that it was caused by a virus. Anne wondered if the children had been exposed to a virus in the air or perhaps in the tap water.

In *A Civil Action* author Jonathan Harr provided Anne's thoughts at the time:

> "The notion that each case shared some common cause began to obsess her. 'The water and the air were the two things we all shared,' she said in a deposition some years later. 'And the water was bad. I thought there was a virus that might have been transmitted through the water, some kind of leukemia virus. The water had never tasted right, and it never smelled right. There were times when it was worse than others, usually during the summer, and then it was impossible to drink. My mother would bring some water from Somerville to the house on weekends, probably about three quarts, which we used as drinking water. The rest of the time, when we could mask the flavor of it with Zarex or orange juice or coffee or whatever, then we used water from the tap. But you couldn't even mask it. It ruined the dishwasher. The door corroded to such a degree that it had to be replaced. The prongs that hold the dishes just gave way and broke off. On a regular basis, the pipes under the kitchen sink would leak, and under the bathroom sink. The faucets had to be replaced."

(audio)??

In fact, the water had not always been a problem. Complaints about the water in east Woburn began after Well G began pumping water in November of 1964. (The Andersons had moved to Woburn in 1965.) Even more water was needed, and Well H began pumping water in 1967. Wells G and H primarily served residents in east Woburn, although some water went to residents in northern and central areas. In the summer of 1967 high bacteria counts were found in the water from Wells G and H, and the Massachusetts Department of Public Health threatened to close the wells unless the water was chlorinated. Chlorination was begun in 1968, but the complaints about the odor, taste, and rusty color of the water continued. Complaints forced the major to stop pumping in October 1969, but they were reopened whenever the demand for water increased during the summer or when there was drought. Whenever Wells G and H began pumping, there were complaints about the "putrid, ill-smelling, and foul water."

Anne Anderson tried to convince her husband, Jimmy's doctor, and town officials that something was wrong, but her concerns were dismissed. The cause of ALL was unknown, and the feeling was that the occurrence of this small cluster of leukemia cases was just a random occurrence. In addition, chlorination had reduced the bacterial counts in the water to safe levels, and the town engineer stated that the water was safe.

Given these concerns, how can we begin to investigate whether something in the environment is responsible for health problems in the community?

Assessing the Health Status of a Community

In order to monitor the health of a population it is necessary to record health related events. The earliest systematic records regarding health status of a community were records of births and deaths that were recorded in Europe beginning centuries ago. Around 1592 the parish clerks in London began recording deaths. In 1662 John Graunt, a founding member of the Royal Society of London, summarized the data from these "Bills of Mortality" in a publication entitled "Natural and Political Observations Mentioned in a Following Index, and Made Upon the Bills of Mortality." Graunt analyzed the data extensively and made a number of observations regarding common causes of death, higher death rates in men, seasonal variation in death rates, and the fact that some disease had relatively constant death rates, while others varied considerably. In 1837 England established the General Registrar's Office in order to record births, deaths, and marriages in England and Wales. Dr. William Farr was appointed Chief Statistician, and the data that was collected was used by John Snow and by Edwin Chadwick to explore the determinants of disease by looking at how disease rates differed according to factors such as gender, location, occupation, and social class. Measuring disease frequency and making comparisons among groups of people is essential to identifying the determinants of disease and health.

Massachusetts played a leading role in the evolution of surveillance in the Americas, beginning with registration of births and deaths in 1842. Lemmuel Shattuck headed the Sanitary Commission of Massachusetts, which submitted its "Report of a General Plan for the Promotion of Public and Personal Health" in 1850. In 1874 Massachusetts established a surveillance system that would be described today as "sentinel surveillance" in which a specified group of 168 physicians submitted regular reports on new cases of 14 diseases deemed "dangerous to the public's health." Ten years later the legislature established a list of "reportable diseases," which all physicians were required to report, subject to fine.

Birth certificates and death certificates continue to play a role in health surveillance.

Birth Certificates

Birth certificates record useful information on live births, but the format and degree of detail varies by state, but all birth certificates contain useful information for health investigations: sex, residence of parent, birth weight, and occurrence of birth defects. Public health officials can analyze data from birth certificates, but birth certificates are generally confidential and not accessible by the general public.

Death Certificates

In most US states, death certificates are public records, although some states, e.g., New Hampshire, do not permit public access. In other states access to the record can be limited by the family of the deceased, and in other cases the cause of death is withheld. While the format varies from state to state, death certificates usually indicate :age, sex, race, cause of death, date of death, address, and usual occupation of the deceased. Nevertheless, aggregate data from death certificates is usually available in state or federal offices that provide Vital Statistics. A common problem with death certificates is that there are no strict criteria for classifying the cause of death, so there are many inconsistencies and errors in classification which can introduce misclassification bias into an analysis. For more information about the effects of misclassification of outcomes, which is found in the online learning module on Bias.

The National Death Index (NDI) and Social Security Death Index (SSDI) are two online databases that have mortality data. Data from the SSDI can be accessed by the general public, but one must apply for access to the NDI and pay a fee..

Other Sources

Today there are several other excellent sources of information that were not available when Jimmy Anderson was diagnosed with leukemia in 1972.

Cancer Registries

Most states now have cancer registries that provide an important means of monitoring cancer rates among the communities in a given state. Massachusetts did not have a cancer registry when the Woburn leukemia cluster was discovered. In fact, the health issues in Woburn were instrumental in the establishment of the Massachusetts Cancer Registry in 1980, and Dr. Richard Clapp, a professor at the Boston University School of Public Health was its first director. In the video below Dr. Clapp discusses the founding of the registry and its importance.

Community Health Reports

Some states provide readily accessible reports and health related data. In Massachusetts MassCHIP provides community-level data to assess health needs, monitor health status indicators, and evaluate health programs. Health care providers, state and federal agencies, universities, community health centers, and local boards of health can all find information relevant to their fields by using MassCHIP. The iFrame below provides access to MassCHIP.

Note that there are prepared reports for many potential health issues. In the column on the far left there is a link for "Cancer," which takes you to a page with links for many specific types of cancer, including leukemia. If you go to the page for leukemia, you will see a number of links, one of which is for "Cities and Towns". This, in turn, brings you to a page that will provide reports on leukemia rates for all of the cities and towns in Massachusetts.

On the next page of this learning module, we will address the calculation and interpretation of "standardized incidence ratios" or SIRs, which provide a way of answering the question of it is unusual to see 12 cases of leukemia in a community like Woburn.

For more information on assessing disease in communities see the online learning module on Surveillance, which includes these specific topics that may be of interest:

- Data Sources for Surveillance and Monitoring the Health Status of the Population
- Massachusetts Cancer Registry
- Environmental Public Health Tracking 101
- Surveillance for Infectious Disease

Contamination in Wells G and H

In the spring of 1979 it was discovered that someone had left 184 barrels of industrial waste on a plot of land in northeast Woburn just a half mile from Wells G and H. The barrels were removed before they leaked, but given the proximity to the wells, a state inspector tested water samples from Wells G and H. On May 22 the results showed that

both wells were heavily contaminated with trichloroethylene (TCE), an industrial solvent used to dissolve grease and oil. The concentration of TCE in Well G was 267 parts per billion (ppb), and the levels in Well H were 183 bpp. The wells also contained tetrachloroethylene, also known as "perc," another industrial solvent. The concentrations of both contaminants were above the maximum allowable limits, and the wells were shut down.

Other contaminants had recently been discovered in north Woburn at the site of the old Merrimac Chemical Company. A partially filled lagoon was found to contain arsenic, lead, and chromium. The construction crew that had found the lagoon also found several buried pits containing the rotting remains of animal hides and slaughterhouse waste.
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In the audio file below Woburn Times reporter Charlie Ryan discusses the discovery and extent of the contamination found in the area of Wells G and H.

(audio)

The Leukemia Cluster

There was widespread concern In the wake of the disclosures about the contaminants found at the old Merrimac Chemical Company and the contamination of Wells G and H with TCE and perc. Reverend Bruce Young, the minister at Trinity Episcopal Church in Woburn, had had many conversations with Anne Anderson about her belief that something in the environment was responsible for the leukemia cases in Woburn; by this time Anne knew of eight cases. When Reverend Young read the newspaper reports, Anne's beliefs suddenly seemed credible. It seemed to Young that the next logical step was to determine how many cases of leukemia there were in Woburn, but at the time neither the state nor the city had a surveillance system that kept track of incident cancer cases.

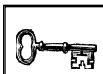
When confronted with an unusual case of disease or an unusual cluster, one of the key things that should be done is to actively look for more cases. If one can develop a case series, it makes it easier to figure out how the occurrence of disease relates to personal characteristics, place (where the cases lived or worked), and time (when the disease cluster began and how the frequency of disease changed over time).

For a more detailed discussion, see the online learning module of Descriptive Epidemiology.

Reverend Young decided to "...write a letter to be published in the *Woburn Daily Times* asking parents who had a child diagnosed with leukemia in the last fifteen years to come to a meeting at Trinity Episcopal." [Source]

More than thirty people attended the meeting on October 4, 1979, including parents of children with leukemia and concerned citizens. reverend Bruce distributed a survey, and when they were returned, they had identified 12 leukemia cases over a 15-year period. Eight of the cases occurred in east Woburn, and six of those were in the Pine Street neighborhood.just south of the "Fifteen Acres" plot of land and Wells G and H.

Was this really a cluster? Some epidemiologists attributed apparent clusters to the "Texas Sharpshooter Effect." Was the apparent cluster in the Pine Street area of Woburn real?



The key question, of course, was whether twelve cases of childhood leukemia over a 15-year period was unusual for a population like this.

In December 1979 the CDC asked the city of Woburn for permission to investigate the possible leukemia cluster. Jonathan Harr described the planning of the study as follows:

"With help from the Massachusetts Department of Health, an epidemiologist from Atlanta began designing a study for Woburn. Trained researchers from the department of health would be sent to the homes of the twelve families with leukemic children and conduct in-depth interviews on a wide range of subjects. The researchers would also interview twenty-four other Woburn families that had been selected as controls, matched by age and sex with the leukemic families. The study, said the experts, would take a year to complete."

from A Civil Action by Jonathan Harr, Vintage Books, 1996

Test Yourself

Test Yourself

Test Yourself

1979: Woburn Health Data Analysis, 1969-1978

On December 21, 1979 the Massachusetts Department of Public Health published the Woburn Health Data Analysis, 1969-1978.

The summary of the report stated:

"The Department of Public Health has ascertained that Woburn's cancer death rate is higher than what should be expected considering the age and sex characteristics of its residents. However, we have not found data that associates a cause and effect relation between the Woburn cancer death rate and any specific cause. The Department has also determined that although the statistics are higher than what we would expect, they do not represent an epidemic situation. They do present some serious questions that need answers which we intend to pursue."

And the concluding paragraph said:

Cancer Mortality as an Indication of Cancer Incidence
"The Department of Public Health does not have incident or morbidity data on cancer that is available to the Department. There is no formal mechanism in Massachusetts for collection of comprehensive population based data on cancer incidence. For cancers such as lung cancer with high mortality experiences, mortality profiles reflect accurately cancer incidence; for cancers such as skin cancer with low mortality, mortality data does not present a

> complete picture. Under any circumstances, mortality is the most widely used and readily available measure of health status. It is the best index presently available."

The aggressive efforts by Reverend Young to find all of the leukemia cases had successfully identified all 12 of the incident leukemias that occurred during this 15-year period. However, the problem was that there was no way of knowing whether this incidence was unusual, since there was no data on cancer incidence in other communities in Massachusetts. As a result, the key question about whether 2 leukemia cases in a 15-year period was unusual remained unanswered. The lack of data on incident cases of cancer was a major limitation, and the following year the Massachusetts Cancer Registry was created and began to collect the data necessary to answer questions like this.

1981: Woburn - Cancer Incidence and Environmental Hazards, 1969 – 1978

Jimmy Anderson died on January 18, 1981. Five days later the Massachusetts Department of Public Health and CDC released an additional study that and concluded that the incidence of childhood leukemia in Woburn was significantly greater than expected. This study got around the lack of information in the rest of the state by using age- and sex-specific incidence data from the Third National Cancer Survey (TNCS). The key data for this comparison are summarized in Table 5 at the end of the study.

This investigation also included a case-control study; the Methods section of the published study described the case-control study as follows:

> "The study questionnaire was developed, pretested, and revised by the MDPH and the CDC. The topics investigated included demographic information, disease process, past medical history, smoking, residence, schooling, occupational histories, and environmental exposures. The majority of the interviews were conducted by trained interviewers from the CDC and NIOSH. Two age and sex-matched controls were interviewed for each of twelve childhood leukemia cases. One control was a person of the same age and sex who lived close to the case. The other age and sex-matched controls lived in a distant part of Woburn. Interviews were conducted with one or both parents of the leukemia cases and controls."

The case-control study did not demonstrate any significant differences between the cases and controls that might provide clues about the cause of the cluster. Nevertheless, the comparison in Table 5 of the study did indicate that the incidence of leukemia was higher than expected based on a comparison with data from the Third National Cancer Survey.

Exactly how did these investigators determine that the incidence of leukemia in Woburn was unusually high?

Standardized Rates of Disease

As noted earlier, a key question for Woburn was whether or not the community was experiencing an unusually high frequency of leukemia (or other diseases). The strategy for doing this is generally to compare the incidence of a particular disease in a community to the incidence of that disease relative to that in other communities or relative to the overall rates seen in the state or in the country. However, comparisons like this can be distorted by confounding factors, such as age and gender. Imagine, for example, that you are comparing overall rates of cancer mortality in two populations, one of which has a large proportion of older citizens, while the other has a younger age distribution. If the overall cancer mortality is greater in the older population, it would not be valid to conclude that this community has an environmental factor that increases the risk of cancer, because age is another risk factor that independently associated with an increased the risk of cancer mortality. As a result, the comparison isn't fair, because of the unequal age distribution. Age differences always have the potential to confound these comparisons, because so many health outcomes are affected by age. Many health outcomes are dependent on gender, so differences in gender distribution between two populations can also introduce confounding.

When comparing rates of disease among communities, the problem of confounding by age or gender can be dealt with by computing age-standardized rates separately for males and females. There are two techniques for doing this.

1. **Age-adjusted Standardized Rates** - One can calculate age-adjusted standardized rates from the age-specific rates of disease for each of the populations to be compared. If age-specific rates of disease are available for the populations being compared, one can then use a standard age distribution to compute a hypothetical summary rate that indicates what the overall rate of disease would be for each population, if they had had the same age distribution as the standard. In other words, one uses each population's real age-specific rates and applies these to a single standard age distribution.
2. **Standardized Incidence Ratios** - In some situations the age distribution of the populations being compared is know, but it is difficult, if not impossible, to obtain reliable estimates of age-specific rates if the disease is rare or if one or more of the populations is small. In these situations the age-specific rates would be subject to random error because of relatively small numbers of observations. In this situation one can compute a standardized incidence ratio which addresses how the observed number of cases of disease in a community (like Woburn) compare to the number of cases that would have been expected if the community had had the same rate of disease as the comparison population.

Standardized rates are explained in detail in the online learning module on Standardized Rates. Review the module paying particular attention to the section on standardized incidence ratios on page 6. As the module indicates, standardized incidence ratios are particularly useful when dealing with relatively uncommon diseases, such as leukemia. The strategy for SIRs is to compare the number of observed cases of disease to the number of cases that would have been expected if the community's rate of disease were the same as the overall rate for the state. Consequently, an important application of SIRs is to monitor the frequency of cancer and other diseases in individual communities. The Massachusetts Cancer Registry was established in 1980, partly in response to the childhood leukemia cluster in Woburn.

Review the examples in the module on Standardized Rates to familiarize yourself with calculation of an SIR; then use this information to compute the SIRs for leukemia in male and female children in Woburn using the data in the tables below.

The tables below summarize data that were used for computation of standardized incidence ratios in both the 1981 report (Woburn - Cancer Incidence and Environmental Hazards, 1969-1978) and in a a subsequent article published in 1986 (Cutler JJ, Parker GS, Rosen S , et al.:"Childhood Leukemia in Woburn, Massachusetts." Public Health Reports, March-April 1986; 101(2):201-205). The tables (for males and females) provide age-specific information on populations size, overall rate of leukemia in MA, and the observed number of leukemia cases in Woburn for the period 1969-1979. The numbers of expected cases were determined from the Third National Cancer Survey, 1969-71, as described in the article.

Following the example on page 6 of the module on standardized rates, compute the missing information in the tables below, and use this to compute the SIR for male children and the SIR for female children. Complete your calculations and interpret your findings before looking at the answer.

Male Children (1969-1976)

Age Group	Population	State Rate	Observed Cases	Expected Cases

Female Children (1969-1976)

Age Group	Population	State Rate	Observed Cases	Expected Cases

<5	1784	0.0008	4	?
5-9	2057	0.0004	3	?
10-14	2128	0.0003	2	?
SUM	5969	------	?	?

<5	1714	0.0007	0	?
5-9	1982	0.0004	0	?
10-14	2083	0.0002	3	?
SUM	5779	------	?	?

ANSWER

Go to the Massachusetts Cancer Registry web site and find the City & Town Series. Open the City and Town Supplement for 2005-2009 and scroll down until you find the report for Woburn. What are the SIRs for leukemia in males and females during this five-year period? What are the 95% confidence intervals for the SIRs? How would you interpret these SIRs?

ANSWER

The image in the answer needs to be photoshopped.

The previous analyses suggest that the incidence of childhood leukemia in Woburn from 1969-1976 was unusually high, but what exposure(s) or factors were responsible for the increase? A logical next step might be to assess the contaminants to which the community has been exposed.

Data on Environmental Contaminants

Sources of environmental information have improved a great deal since 1972 when Jimmy Anderson was diagnosed with leukemia. Today, when community members or health professionals have suspicions about an environmental contaminant causing health problems, one of the first steps should be to learn about the environmental quality of their community. Some questions they should ask are::

- Whether there are any hazardous waste sites in the community?
- What active industries are there?
- Are there specific chemicals that may be hazardous?
- How can one find out about the air and water quality in our community?

Data on the environment are routinely collected by federal, state, and local agencies.:

- U.S. Environmental Protection Agency (EPA - http://www.epa.gov/)
- State departments of the environment and public health, e.g.:
  - Massachusetts Department of Environmental Protection (MassDEP - http://www.mass.gov/eea/agencies/massdep/)
  - Massachusetts Department of Public Health (Massachusetts DPH - http://www.mass.gov/eohhs/gov/departments/dph/))
- Local boards of health, fire departments, and water companies

Other agencies also collect environmental data, but these are the best sources to start with.

Hazardous Waste Sites

In Massachusetts a good first step would be to contact the Massachusetts DEP and ask for the Hazardous Waste Division. In some states, the public health department may handle hazardous waste.

Once you have found the right person, ask if there are any:

1. Superfund sites
2. Any other hazardous waste sites

> Superfund is the name given to the environmental program established to address abandoned hazardous waste sites. It is also the name of the fund established by the Comprehensive Environmental Response, Compensation and Liability Act of 1980, as amended (CERCLA statute, CERCLA overview). This law was enacted in the wake of the discovery of toxic waste dumps such as Love Canal and Times Beach in the 1970s. It allows the EPA to clean up such sites and to compel responsible parties to perform cleanups or reimburse the government for EPA-lead cleanups.

Today, many resources are available on the web. The iFrame below is from the Massachusetts DEP web page on Cleanup of Waste Sites & Spills. Pay particular attention to the link for Cleanup Sites & Locations. There are several Superfund sites in Woburn, including Wells G and H. These resources did not exist when Anne Anderson began her quest for information. Superfund was not established until 1980. Massachusetts keeps an additional list of hazardous waste sites. This list includes everything from leaking underground storage tanks at gas stations to small dumpsites.

On that page, the link to Site-Specific Information provides a wealth of information on the Woburn site:

- U.S. EPA Information on the Superfund Site or the National Priorities List (NPL)
- MA Department of Public Health (DPH) Information on the site

Identifying Active Industries

Another important step when investigating environmental concerns in the community would be to identify active industries that use hazardous materials.

- Where are these industries located?
- What specific chemicals are they using or producing?
- Where do these chemicals end up? How are they disposed of?

Keep in mind that it is **legal** to emit hazardous pollutants into the air, water, and land, but there are specific regulations and policies that govern this. Facilities must first register with the state DEP and EPA (federal), and they obtain a permit. States will have permit information on all facilities on file. In addition to these "permitted" and intentional releases of chemicals, accidental or "fugitive" releases also occur. The best source of data for an overall snapshot of a town's industry is the EPA's Toxics Release Inventory (TRI).

The Toxics Release Inventory (TRI)

Under a federal law passed in 1986 (The Emergency Planning and Community Right-to-Know Act) most large industries must submit annual reports to the EPA detailing how much of certain hazardous chemicals are released to the air, land, or water. Over 300 toxic chemicals are subject to reporting. EPA is required to make this information

available to the public. The first year for which data is available is 1987. The TRI data and related information are available through a number of sources.

The EPA's Toxics Release Inventory Program.- The TRI lists, by town, the facility name, chemical, and how many pounds (per year) were released. The report indicates whether releases were to the air, to water, in waste injected underground, to land on the facility property, transferred to a sewage treatment plant publicly owned treatment works, or in wastes transferred off the property for disposal. The CAS number, which is used to uniquely identify the particular chemical, is also given. This is helpful, as some chemicals have several names and often the same name is used for more than one chemical.

You can also request additional information from the TRI, such as:

- What the chemical is used for
- The maximum amount of the chemical that is stored at any one time at the facility
- Actions the facility might be taking to reduce their releases.

TRI is a valuable source of data. However, it is important to be aware of TRI's limitations:

1. TRI began in 1987. This source would not have been available to Anne Anderson.
2. Not all industries are required to report to TRI. There are certain requirements that industries must fulfill before they have to report: (a) they must have at least 10 full time employees; and (b) they must handle a minimum amount (called threshold amount) of each chemical (at least 10,000 pounds).
3. There are some 300 chemicals that must be reported, but chemicals not on this list do not have to be reported. Loopholes exist -- hazardous waste incinerator emissions and chemicals claimed to be recycled are not reported, nor are materials released by the military. Also note that reported quantities are based on facility estimates, not direct measurements.

Additional information can be obtained from a number of excellent sources:

- TOXNET - which provides multiple very useful databases including the Hazardous Substances Data Bank (toxicology for > 5,000 substances), LactMed (drugs & chemicals affecting breastfeeding), TOXMAP (interactive maps of Superfund data, US Census, and National Cancer Institute data), CCRIS (Chemical Carcinogenesis Research Information), DART (Developmental and Reproductive Toxicology Database. References to developmental and reproductive toxicology literature), Household Products Database (potential health effects of chemicals in more than 10,000 common household products), and several others.
- Toxnet Fact Sheets from the National Library of Medicine
- State Emergency Response Commissions (SERCs) [This link provides a page with links to the SERCs for all 50 US states.]
- Local Emergency Planning Committees (LEPCs)
- The Right to Know Network - RTK-Net includes advanced tools for analysis of TRI data, as well as water permitting data.
- The Occupational Safety & Health Administration (OSHA)
- Local fire departments often have safety records for the TRI facilities in a community.

We wrote to the EPA and requested a list of all chemicals released to air, water, and land for Woburn that are listed in the TRI for 1987. In this example the release was a "fugitive" release to the air. This means that the release was unconfined; the chemical may have escaped by evaporation, for example, as opposed to air emissions, which are released from a discrete source such as a stack. ***[Do we have this example?? WL]*** ***We can Google Toxics Release Inventory 1987 and get a ZIP download of data from 1987-2012. Can we use this? WL***

Air Quality

TRI contains information on the yearly totals industries release into the air. However, TRI does not tell you if these "releases" occurred in heavy bursts or in slow continuous releases. There is also no information on whether the emissions mix with the air and are dispersed over a wide area or stay trapped near the ground, and there is little information about the overall quality of the air in a given community.

Water Supply

A community's water supply is an important route by which people can be exposed to hazardous chemicals. Federal and state laws require testing of water supplies at specific intervals, although many industrial contaminants may not have been measured, particularly for years prior to 1989. Information about water quality in a community might be obtained from the local water department, county health department, or state department of the environment. It is also important to determine whether any sources of hazardous waste were located in proximity to wells or reservoirs.

Community Organizations

Concerned citizens might also look for community organizations that focus on environmental issues. Also, the Environmental Clearinghouse which "...enables effective public participation in crucial environmental decisions by connecting public interest groups with legal and technical experts."

Historical Data on the Environment

Information on environmental contamination occurring prior to the 1980s is limited, but there are other potential sources such as:

- City annual reports (which sometimes date back to the 1800s) describing the industries and how much they produced.
- City Clerk and Assessors Offices maintain records of past land use.
- The Fire Department has copies of past and present flammable material permits, and violation notices.
- The State Board of Health has detailed reports, sewer permits, and inspection records for each city and town.
- The local libraries have old newspaper articles. They also have insurance maps, and other old City maps which show the location of industries over time.
- Historical societies and trade associations are further sources of information that have been useful.

The Link Between Exposure and Disease

The investigation in Woburn evolved in an unusual fashion. There were certainly suspicions by Ann Anderson and others that something in the environment was responsible for the leukemia cases that were occurring, but their concerns were largely dismissed by town officials. The contamination of Wells G and H with TCE and PCE was discovered somewhat accidentally when an unknown person left 184 barrels of waste on a plot of land. Even just north of the wells. The barrels were discovered and removed before they had contaminated the soil, but a town engineer submitted samples of water from the wells that lead to discovery of the contamination of TCE and PCE. In fact, it was this discovery of TCE and PCE in the wells and heavy metal contamination at the site of the old Merrimac Chemical Company that prompted Reverend Young to search for additional cases. These events drew the attention of the Massachusetts environmental officials and the EPA who conducted the series of studies described previously in this module. They concluded that the incidence of leukemia in Woburn was higher than expected based on the statewide average, but now several questions remained to be answered:

- Who was responsible for contamination of the wells?
- To what extent had had the water supply been contaminated prior to 1979?
- Did the elevated concentrations of TCE and PCE in the wells cause leukemias in the children?

In 1982, Rev. Bruce Young and Anne Anderson approached staff at the Harvard School of Public Health and asked for assistance in some kind of further health study. Dr. Marvin Zelen and others responded and planned a cross-sectional interview study to see if childhood leukemia, birth defects, and other childhood illnesses were associated with exposure to water from Wells G and H. A major volunteer effort was mobilized, and over 5,000 households were contacted and queried about their health. When the results were presented in 1984, the first link to the Wells G and H was made in a scientific study. They concluded that the children who had leukemia received twice as much contaminated water as the children who didn't. This study also led to the recognition that ordinary citizens could play an important role in the design and conduct of

epidemiological studies. Results of the study were published in 1986 (Lagakos SW, Wessen BJ, and Zelen: An analysis of contaminated well water and health effects in Woburn, Massachusetts. J. Am. Stat. Assn 1986;81(395):583-596.)

The authors stated,

> "Our objective was not to compare these rates [of leukemia] with those elsewhere but to determine whether space-time distribution within Woburn of the 20 cases was correlated with access to water from wells G and H. Using a test derived from Cox's (1972) regression model, we found that both a "cumulative" and "none-some" metric of G and H exposure were positively associated with leukemia rates. It does not appear that Woburn's entire leukemia excess, based on national rates, is statistically explainable by wells G and H."

In the discussion, they offered the following comments:

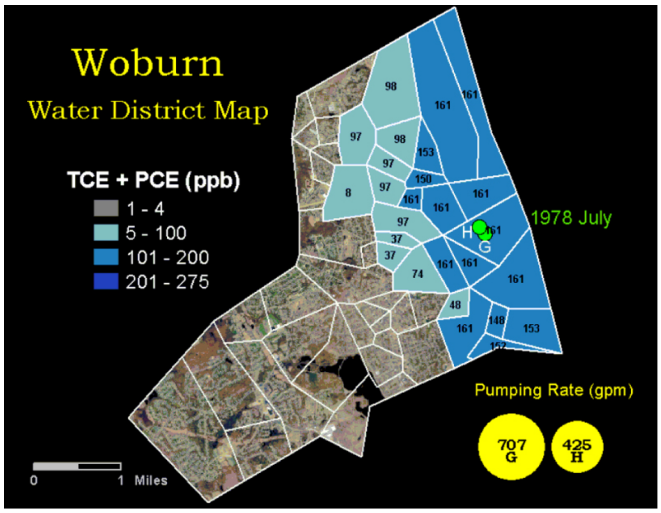
> "A difficulty in trying to determine whet in her wells G and H caused any adverse events is the lack of knowledge about the contaminants in wells G and H and the effects of these contaminants on human health. Several of the chemicals detected in 1979 have been shown to cause cancer in laboratory animals when given in high concentrations, and others found in the surrounding groundwater are suspected of causing cancer in humans. The effects on humans, however, of exposure to these chemicals at lower concentrations and in combination are not well understood. Furthermore, the types and levels of contaminants in wells G and H prior to 1979 are not known. Thus wells G and H might have become contaminated shortly before they were tested in 1979, or might have been contaminated for many years, at much higher levels and with chemicals other than those found in 1979. The EPA is currently conducting geological studies to determine the sources of the contaminants found in wells G and H and the surrounding groundwater. These studies might make it possible to predict the types and levels of contamination in earlier years. Without this information, it is unlikely that the role of wells G and H as a cause of adverse health outcomes will ever be fully understood.
>
> A key question among citizens is whether individuals who were formerly exposed to wells G and H might still be at elevated risk. One way this can be investigated is by monitoring adverse health outcomes in Woburn over the next few years."

The animation in the video below shows a model of how TCE from 5 sources was likely to have moved in groundwater from 1960 to 1986 and ultimately contaminated Wells G and H. Keep in mind that movement of ground water was affected by the composition of the soil and other geologic materials (e.g., bed rock) in the buried valley beneath the Aberjona River, pumping of Wells G and H (which were operated intermittently as shown in the animation), and by drought conditions and flow in the Aberjona River. Note also the persistence of the TCE plumes in groundwater.

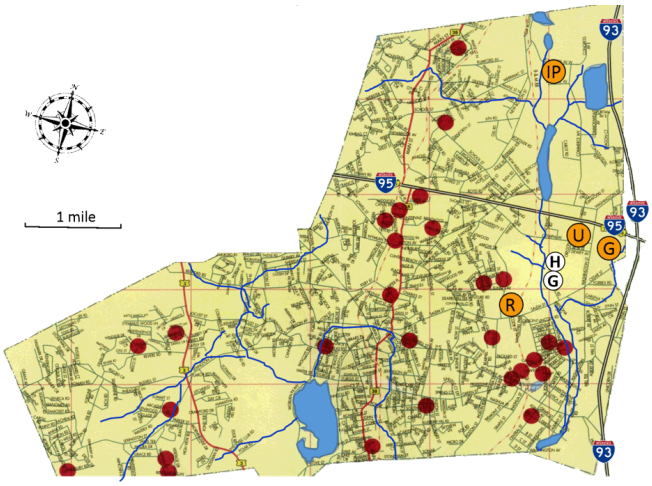
Animation by Scott Blair, Ohio State University, Department of Geological Sciences

Source: Carleton College; http://serc.carleton.edu/NAGTWorkshops/hydrogeo/activities/10688.html

The water from Wells G and H was mixed with water from other water sources in Woburn, so the degree of contaminated with TCE and PCE varied. The maps below examine the spatial relationships between TCE and PCE levels in the water supply to various parts of Woburn and the occurrence of leukemia. The map on the right is adapted from a map constructed by FACE (the citizen organization For A Cleaner Environment). The red circles identify the residence of 28 leukemia victims from 1960 to 1986. Wells G and H are shown in gray circles. The orange circles show the location of some of the contaminated sites. "R" is the Riley Tannery; "IP" is the Woburn Industri-Plex; "U" is the plant; and "G" is W.R. Grace.



Source: http://serc.carleton.edu/woburn/resources/OSU_animations.html



Adapted from http://serc.carleton.edu/details/images/8137.html

What conclusions do you draw from these maps?

Note that there is a paucity of cases in the northeastern part of Woburn despite high concentrations of contamination along the eastern border. What might account for this?

Clearly the wells G and H were contaminated with TCE and PCE in 1979, but how does one go about assessing the extent of human exposure? What variables should be taken into account?

Assessing Human Exposure

TCE and PCE were clearly present in the the water from Wells G and H in 1979, but it was not known when the contamination began or how severe it had been over the years leading up to 1979. Jimmy Anderson and several other children had been diagnosed with leukemia prior to 1973. If TCE or PCE were responsible, they would have had to have been present in the water prior to that. The exact course of event was unknown, but the models developed by hyrdogeologists suggested a plausible time course for contamination of the wells.

At the time, very little was known about these chemicals, and they were not known to cause childhood leukemia. Investigators would have wanted to find out as much as possible about these chemicals, including how they behave in the environment, their toxicity, how humans may be exposed, and who may have been exposed. Much of what is now know about TCE and PCE was learned after Woburn (and in some cases because of Woburn), but if you were confronted with a similar problem today, you could investigate these chemicals by considering several important aspects of exposure assessment.

Refer to the Exposure Assessment module (link) first, and then apply what you have learned to these chemicals.

Fate and Transport

The fate and transport describes how a particular chemical will behave in the environment or media and how or if it will come into contact with humans. Understanding the media in which an agent is found will allow you to understand the ways in which humans may be impacted. In Woburn, the chlorinated solvents (TCE and PCE) were discharged, or dumped, into the soils. The solvents were transported by rainwater into the groundwater which discharged into the Aberjona River. The chemicals remained in their original forms, but there was some degradation in the groundwater to a chemical called vinyl chloride, a known human carcinogen. The groundwater was used as the drinking water source for many Woburn residents.

Read more information about TCE in the environment.

Toxicity

The toxicity of an agent or chemical describes how poisonous it is. Since there are many different endpoints, or health effects, that may result from exposure to a particular agent, it is important to consider all possible health effects that have been identified for that agent. From the inventory of chemicals identified in Woburn, you would want to consider the toxicity of the chlorinated solvents: dichloromethane, trichloroethylene (TCE), and perchloroethylene (PCE) on the basis of the available toxicity information and concentration in drinking water. Two good sources of information on the toxicity of individual chemicals are ATSDR and IRIS. Explore these web sites for information regarding TCE.

- ATSDR: http://www.atsdr.cdc.gov/
- IRIS: http://www.epa.gov/IRIS/

You can also find out how TCE is classified by IARC by searching the IARC web site.

Read more information here about the toxicity of TCE:and the EPA's Toxicological Report of Trichloroethylene.

Amount

The amount of a hazardous agent present in the media of concern should be considered, as the risk of developing a health effect is a function of both the amount and toxicity of the chemical.

In 1979, Wells G and H were tested and found to be "heavily contaminated" with TCE. TCE was measured in Wells G and H at levels of 267 ppb and 183 ppb, respectively. This was much higher than the federal maximum contaminant level at the time.

Exposed Population

Primarily the residents of the neighborhood East Woburn were using contaminated water. These residents included adults, pregnant women, and children. The greatest leukemia risk was in children whose mothers drank contaminated water during pregnancy. Fetuses and children are particularly sensitive or vulnerable to the effects of certain agents.

Routes of Exposure

How humans are exposed is important to consider, as agents of concern may have different toxicities depending on the routes of exposure. In Woburn, the residents were exposed to chlorinated solvents by drinking the contaminated water, inhaling the vapors of the solvents while bathing and showering, and dermally contacting the solvents while bathing and showering.

Exposure Duration and Frequency

It is important to determine the frequency and duration of exposure to an agent. Toxicity is a function of several factors including how long exposure occurs (duration) and how frequently the exposure occurs during that time period. In general, the more frequent the exposure, the greater the possibility that adverse health effects will occur on the largest number of people. Similarly, the longer one is exposed to a toxic chemical the more likely that person is to experience health problems. We would be interested in finding out how long the companies in Woburn have been in operation and how long they have released these chemicals. We also would like to know if the releases occur slowly and consistency, or in periodic, heavy bursts.

In Woburn, the residents were exposed to solvents in drinking water several times daily while drinking, bathing, and washing dishes. Thus the frequency is represented here as several times per day, or daily. If the vapors were present in the homes from either an indoor or ambient source, then the inhalation exposure would be continuous.

Community Based Participatory Research

Community-based participatory research (CBPR) is a collaborative approach to research that encourages equal representation of community members and researchers in all aspects of research -- from conception to conduct to communication of results. CBPR is an effective method for community members and researchers to combine knowledge to improve community health.

Learn more about CBPR here: http://obssr.od.nih.gov/scientific_areas/methodology/community_based_participatory_research/

In Woburn, the citizens group FACE (For a Cleaner Environment) was one of the earliest examples of the concept of CBPR. This group was comprised of many parents of sick children, as well as other concerned citizens, and included the Reverend Bruce Young and Anne Anderson. FACE was instrumental in the initiation of early health studies in Woburn, after they approached researchers at the Harvard School of Public Health. FACE was also involved in the remediation of Wells G and H.

As demonstrated by the involvement of FACE in the Woburn story, CBPR has an important place in environmental health research. Several journals are dedicated to this method:

https://www.press.jhu.edu/journals/progress_in_community_health_partnerships/

http://participatoryresearch.web.unc.edu/journals-for-participatory-research/

There is also a CBPR listserv if you'd like to learn more about CBPR:

http://ccph.memberclicks.net/

Remediation and Superfund

Many of Woburn's contaminated sites, including Wells G and H, were so badly contaminated that they were placed on state and federal lists to be investigated and "remediated" (contained or cleaned up if possible). Some of these sites were declared Superfund sites; FACE formed citizen advisory committees to oversee the cleanup process at two of these large federal Superfund sites in Woburn.

Superfund is the program established to address hazardous waste sites and is also the name of the fund established by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980. It allows the EPA to clean up such sites and to hold compel responsible parties accountable. Learn more about Superfund here:

http://www.epa.gov/superfund/about.htm

Remediation

The Superfund cleanup process is complex. It involves the steps taken to assess sites, place them on the National Priorities List (NPL), and establish and implement appropriate cleanup plans. Learn more about the remediation process here:

http://www.epa.gov/superfund/cleanup/index.htm

Find Superfund Sites Near You

Use this tool to find Superfund sites near you:

http://cumulis.epa.gov/supercpad/cursites/srchsites.cfm

The Lawsuit

See also http://home.comcast.net/~dkennedy56/woburn_trial.html //WL

1980s: Remediation and Lawsuit

Anne Anderson and other families in Woburn met with attorney Jan Schlictman in 1981 to discuss the possibility of a lawsuiit.

In 1984 Anne Anderson testified at hearings chaired by Senator Ted Kennedy. Reverend Bruce Young, Anne Anderson, and other Woburn parents spoke about their concerns and the significance of the studies in the hope that they would provide funding to clean up the nation's worst toxic dumps.

President Reagan was proposing to downsize government, and a massive budget deficit loomed in the background. Nevertheless, the testimony of Woburn parents and panic-stricken residents of Love Canal, NY put a human face on the need for a national cleanup. Superfund, the common name for the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) became a law in 1980 and was later funded with 9 billion dollars. (video)

In 1982, a formal complaint against W.R. Grace, Beatrice Foods (Riley Tannery), and UniFirst was filed by Anne Anderson and seven other plaintiffs. The defendants denied that they had caused the pollution of the wells and that the contaminants, primarily TCE, were responsible for the leukemia cases.

Remediation of the Superfund sites began, with the intention of making the water in Wells G and H of potable quality at some time as far as **50 years** in the future. In 1988, EPA concluded its own detailed investigation that demonstrated that groundwater contamination came from five properties located around the municipal wells, designating roughly $68 million to cleanup costs. The lawsuit and subsequent appeals ended in 1989, with a commitment on the part of the responsible parties to contribute to the costs of remediation. "

"In May 1982 Jan Richard Schlichtmann, a young, Cornell-educated lawyer who specialized in medical malpractice cases, filed a lawsuit against two multinational corporations in U.S. District Court in Boston. His clients were six Woburn families, all of whom had a child who had died of leukemia or who was being treated for the illness.

Schlichtmann charged that W.R. Grace & Company, of New York, and Beatrice Foods Company, of Chicago, had contaminated two municipal wells in East Woburn. The suit alleged that the well water caused the leukemia cases and numerous other illnesses," Source

[Note: Below I have inserted an iFrame to a web site at Seattle University School of Law in which they discuss legal aspects of the Woburn case. Wayne]

Woburn - Part 6

Mid-1980s and Beyond: Further Health Studies and the Legacy of Woburn

The Department of Public Health, with assistance from the CDC, organized a national advisory panel to recommend further studies in 1985. A birth outcomes study, termed the Woburn Environmental and Birth Study (WEBS), as well as a leukemia follow-up study, were recommended. The Agency for Toxic Substances and Disease Registry (ATSDR) provided funds for both, and these began in 1988-1989. The WEBS study was released in 1994, with generally negative results. Citizens critiqued it based on the timing of the contamination and the study period.

The Woburn Childhood Leukemia Follow-up Study was an expansion of the original 1981 DPH/CDC case-control study. The follow-up study included more cases and aimed to provide further insight into the causes of childhood leukemia in Woburn. Results were first publicly presented in June 1996 and formally released in 1997. Here, Suzanne Condon, Director of the Bureau of Environmental Health Assessment of the Massachusetts Department of Public Health, discusses the findings, which showed a link between pre-natal exposure to water from Wells G and H and risk of childhood leukemia. In 2002, results were published in the journal *The Science of the Total Environment*. (video)

In 1995, Jonathan Harr published the best-selling book *A Civil Action*, which documented the story of the trial. Later, in 1998, the movie starring John Travolta was released.

The leukemia rate returned to normal for Woburn as a whole. The citizens group FACE no longer functioned, although individual parents continued to speak at public events such as the panel following the premiere of the movie "A Civil Action."

In 2011, the International Agency for Research on Cancer classified TCE as a Group 1 carcinogen, "carcinogenic to humans."

The Legacy of Woburn

"What happened here is really just a symptom of a much larger problem that we see all over this country."

-U.S. Rep. William Lacy Clay Jr., referring to a TCE-contaminated site in St. Louis

Semper Fi, Always Faithful is a documentary that sheds light on the contamination of groundwater that occurred at the Marine Corps Base Camp Lejeune in North Carolina. It follows some of the individuals, or their family members, who developed health effects ranging from childhood leukemia to male breast cancer as a result of exposure to toxic industrial solvents trichloroethylene (TCE), tetrachloroethylene (PCE), and benzene, among others, through their drinking water.

Unfortunately, this is only one of many communities that has been affected by industrial contamination. Two other notable communities include Toms River, New Jersey and Woburn, Massachusetts, both of which experienced increased incidences of childhood leukemia due to TCE and other contaminants in drinking water. In both towns, engaged community members were primarily responsible for bringing awareness to these cancer clusters and for bringing action for remediation.