Woburn

Cancer Incidence and Environmental Hazards
1969 – 1978

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EXECUTIVE SUMMARY

Introduction

The Massachusetts Department of Public Health (MDPH), with assistance from the U.S. Center for Disease Control (CDC), has completed an investigation of possible associations between the incidence of certain cancers and environmental hazards in Woburn for the period 1969 – 1978.

Background

In the spring and summer of 1979 the discovery of hazardous wastes in a section of northeast Woburn called Industri-plex, and the closing of two of Woburn's drinking water wells because of organic chemical contamination, drew attention to environmental hazards in Woburn. Concern over possible adverse health effects from environmental contaminants was heightened when in October 1979 a local clergyman reported on 10 cases of childhood leukemia that had occurred in one area of the town over the prior 15 years. Over the succeeding several weeks the MDPH analyzed Woburn's cancer mortality statistics for 1969 – 1978 and found these mortality rates to be higher than for the state as a whole. At the same time, a Boston pediatric hematologist reported that he had seen six cases of leukemia in one six-block area of Woburn since 1972. In addition, the National Institute for Occupational Safety and Health (NIOSH) was informed of three living cases of kidney cancer among former workers of a now closed pet food plant. These events prompted the MDPH in late 1979 to request the assistance of the CDC in further investigations into the health status of Woburn's residents.

Methodology

This study deals primarily with questions concerning childhood leukemia, renal cancer and liver cancer. Cases with these cancers were investigated by means of an interview study. An investigation into the incidence of bladder cancer was also made. Death certificates, informants and hospital records were the sources utilized to locate cases. A case is defined as a person with confirmed childhood leukemia, renal cancer, liver cancer, or bladder cancer, who was diagnosed with the disease between 1969 and

1978 (1969 – 1979 for the leukemia cases) and who was a resident of Woburn at the time of diagnosis. 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 control lived in a distant part of Woburn. Interviews were conducted with one or both parents of the leukemia cases and controls. Interviews were conducted with the closest available relative of seventeen deceased renal cancer cases, with three living renal cancer cases, and with a relative of five deceased liver cancer cases.

Findings

Analysis of the data was performed by the MDPH in consultation with the CDC. The expected number of incident cases for each of the diseases was calculated using age- and sex-specific incidence data from the Third National Cancer Survey (TNCS).

The investigation has confirmed that there was a significantly elevated incidence of childhood leukemia in Woburn for the period 1969 – 1979. Twelve cases were observed whereas 5.3 cases were expected. The excess leukemias stem primarily from excess cases among males - 9 cases observed, 3.1 cases expected. Analysis of residence at the time of diagnosis reveals a significant concentration of cases in the eastern part of Woburn, where the incidence of the disease was at least seven times greater than expected. For males, the incidence of childhood leukemia in this area was over 12 times that expected. The incidence of childhood leukemia for the rest of Woburn was not significantly elevated compared to national rates.

The incidence of renal cancer in Woburn was also significantly elevated for the period 1969 – 1978. Thirty cases were observed whereas 19.4 were expected. The excess renal cancers stem primarily

from excess cases among males. Analysis of residence at time of diagnosis revealed an apparent geographical concentration of cases in one area of Woburn when residence twenty years prior to diagnosis is analyzed.

The incidence of liver and bladder cancer was not significantly elevated in Woburn. Whereas 7 liver cancer cases were observed, 6.4 cases were expected. The incidence of bladder cancer is somewhat lower than expected in Woburn - 29 cases observed, 45.9 cases expected. Analysis by sex and residence revealed no significant associations of liver and bladder cancer cases with any known environmental factors.

Results of the interview study were essentially negative. Responses to interview questions were generally comparable between leukemia cases and their controls. Analysis of renal and liver cancer case responses revealed no positive leads or associations. In summary, the study failed to identify any relevant factor that distinguished the groups.

Environmental Hazards

Based on interview responses, few of the cases had physical contact with the site where hazardous wastes, including toxic heavy metals, were discovered. Information regarding Wells G and H, which were closed in May 1979 due to organic chemical contamination, indicate that the wells were on line during the presumed critical exposure period of the childhood leukemia cases and that they served primarily the eastern part of Woburn. The data reflect, however, current types and levels of contamination. No information is available indicating what, if any, contaminants existed prior to May 1979. It is important to note that testing of the remaining wells in Woburn has shown that the water meets the federal and state drinking water standards.

Conclusions and Recommendations

The information gathered thus far fails to provide evidence establishing an association between environmental hazards and the increased incidence of childhood leukemia and renal cancer in Woburn. Interviews with parents of leukemia cases, two groups of matched controls, and family members of renal and liver cancer cases revealed no associations between environmental factors and the disease.

The investigation has established that the overall incidence of childhood leukemia was significantly elevated in Woburn and that there was a significant concentration of cases in one particular area of east Woburn. The hypothesis suggesting that the increase in leukemia incidence was associated with environmental hazards in Woburn, and specifically with the contamination of drinking water supplies, is neither supported nor refuted by the study findings. Further investigation of this possible association requires more information. Some of the steps that could provide information that could elucidate the association include the following:

- Attempt to ascertain childhood leukemia mortality and incidence in Woburn prior to 1969, i.e. in the 1950s and 1960s. Findings that childhood leukemia became elevated in the eastern part of Woburn only after Wells G and H came on line would support the hypothesis that the elevated leukemia incidence was related to drinking water contaminants.
- Determine the incidence of other lymphatic disease in Woburn to see if it follows a pattern similar to childhood leukemia over the same time period.
- More generally, determine the incidence of other types of cancer in Woburn prior to 1969.
- Environmental agencies are continuing to attempt to identify the present source of organic contaminants in Wells G and H. This information may help identify past practices of waste disposal and sources of contaminants.

CANCER INCIDENCE AND ENVIRONMENTAL HAZARDS IN WOBURN

I. ABSTRACT

The Massachusetts Department of Public Health (MDPH), with assistance from the U.S. Center for Disease Control (CDC), has completed an investigation of possible associations between the incidence of certain cancers and environmental hazards in Woburn, Massachusetts for the period 1969-1978. The major component of this investigation has been a study of Woburn residents who developed childhood leukemia, renal cancer, bladder cancer or cancer of the liver during this period. The investigation has confirmed that the incidence of childhood leukemia was statistically significantly elevated in Woburn compared to national rates and that there was a statistically significant concentration of cases residing in the eastern section of Woburn. The incidence of renal cancer was also significantly elevated during that period, but not as much as childhood leukemia. The investigation failed to provide adequate evidence to establish an association between known environmental hazards in Woburn and the elevated cancer incidence. Liver and bladder cancer incidence rates were not significantly elevated.

II. BACKGROUND

Woburn is located twelve miles northwest of Boston and was a major leather processing and chemical production center in the 19th and early 20th centuries. Today it is both a residential community and industrial center, with industrial parks housing high technology industries and regional distribution centers (Map 1).

Residents of Woburn and neighboring towns have complained about their water and unpleasant atmospheric odors for at least 100 years.[1] Since the early 1970s, a large area in the northeastern section of Woburn has been undergoing development as a light industrial park. This area was primarily used for agriculture and cattle grazing until 1853, when the land was acquired by a chemical company to build a plant to produce acids and other chemicals for the textile, leather, and paper industries. In 1899

the company acquired an adjacent plant to produce lead arsenite and lead arsenate; between 1899 and 1915, it was the leading U.S. producer of arsenical compounds for insect control. The company produced chemicals through the 1920s, and then animal glues until 1970.[2]

Although the recent concern about environmental quality in Woburn has focused on the northeastern section, it is important to realize that there are potential sources of pollution in many other areas of the town, dating back many years. The major industry in Woburn in the nineteenth century was leather production, and a large number of tanneries were located throughout the town, although most of the tanneries have been closed for many years. Another major activity was the operation of greenhouses, although flower production has also declined considerably in recent years.[3] It is not known whether hazardous residues remain from these or other industries.

During the summer of 1979, national publicity about the contamination of Love Canal in New York, as well as extensive local publicity about possible environmental hazards in Woburn, caused some local residents to wonder if there were higher than average cancer rates in the town. A resident wrote to the CDC asking if cancer rates were elevated in Woburn, but available data were insufficient to provide a definitive answer. In October, a local clergyman, Rev. Bruce Young, reported to the mayor of Woburn and to the press that he had identified 10 cases of childhood leukemia in one area of the town during the prior 15 years. In the succeeding several weeks, the MDPH analyzed Woburn's cancer mortality statistics for 1969 - 1978, and found these mortality rates to be higher than those for Massachusetts as a whole. At the same time, a Boston pediatric hematologist, Dr. John Truman, reported to the CDC that he had seen six cases of acute lymphocytic leukemia in one six-block area of Woburn since 1972. In addition, the National Institute for Occupational Safety and Health (NIOSH) was informed of three living cases of kidney cancer among former workers of a now closed pet food plant in Woburn. This seemed to be an unusually high number of kidney cancers among a workforce thought to be less than a thousand workers when the plant was in full operation. There was also the possibility that additional kidney cancer existed among former workers at the plant which had not yet come to NIOSH's attention.

These events prompted the MDPH to request the assistance of the CDC in planning further investigations of these cases. In December 1979 the two agencies began to formulate plans for the investigation described in this report.

III. WOBURN'S MORTALITY PROFILE FOR THE PERIOD 1969 – 1978

Previous communications from the Department of Public Health to Woburn officials summarized Woburn's mortality experience for 1969 – 1978 based on a preliminary analysis of available data.[4,5] This section of the report will describe in detail that mortality experience. Table 1 presents data for 24 specific causes of death and a summary category, All Causes. The statistics presented are taken from the MDPH publication, "Massachusetts Standardized Mortality Ratios: 1969 - 1978."[6] The methodology for calculating expected numbers of deaths, based on Massachusetts statewide rates, and corresponding levels of statistical significance,[←] is presented in the introduction to that publication. The term "significant" is used in this report exclusively in the sense of statistical significance.

The mortality statistics for Woburn will not necessarily result in the same pattern of elevated rates or statistical significance as the analysis of the incidence of specific cancers in Woburn given below. Mortality data reflect both the occurrence of a specific disease, and also the survival of people with it. Incidence data are an index of the occurrence of a disease, and are thus generally considered a more basic statistic in attempting to analyze causal relations. Also, the expected values used to compute standardized mortality ratios are based on Massachusetts norms, while the expected values used for

[←] Statistical significance is a technical term used to denote the probability (called the p-value) that the difference between an observation or observed value and the expected value is due to chance. If a p-value is low, say - = .05, then we say the finding is statistically significant at the .05 level. A p-value of .05 indicates that there is a 5% probability that the difference is due to random variation and a 95% probability that the observed valued really is different than the expected value. Thus, to say that an observed number of deaths is significantly elevated is only to say that, statistically speaking, the observed number of deaths is not close or equal to the expected number. A significantly elevated mortality rate is not necessarily due to some specific or unusual cause, rather it could be due to the natural variation in the occurrence of the disease.

Various statistical distributions are used to determine these probabilities. The distribution used in this report, unless otherwise noted, is the Chi-square distribution. Two other common statistical distributions are also used several times. These are the Poisson and the Binomial distributions. When the latter distributions are used, the parameters which specify the appropriate calculations are also given.

incidence data are from U.S. statistics, since at the present time there are no incidence data for cancer in Massachusetts.

There were significantly more deaths than expected from all causes in Woburn over the period 1969-1978. While 2,738 deaths were expected based on the statewide experience, 2,944 deaths actually occurred, an 8% excess. Deaths are elevated by about the same amount for both sexes. Although deaths actually declined for both males and females from the 1969 - 1973 period to the 1974 - 1978 period, the expected number of deaths from all causes declined even more over this period. There is a statistically significant excess of deaths from all causes in 1974 - 1978, 13% more than expected. The excess is comparable among both sexes.

Cancer mortality is significantly elevated in Woburn for the 1969 - 1978 period; 13% more cancer deaths occurred than were expected. Cancer mortality follows a similar pattern to total mortality in that males and females experienced a comparable excess of cancer deaths, most of which occurred in the 1974 - 1978 period. In this period, deaths from cancer were elevated by 23%, which is statistically significant. In the period 1969 - 1973 cancer deaths were elevated by only 4%, which is not statistically significant.

Examined by specific cancer type, significantly more deaths than expected occurred in the ten-year period 1969 - 1978 from cancer of the liver, [←] female organs other than the cervix uteri, and kidney. More deaths than expected also occurred for leukemia, cancer of the prostate, breast, bronchus and lung, pancreas, and stomach; for these sizes, however, the differences between observed and expected deaths were not statistically significant. Fewer deaths than expected occurred for cancer of the large intestine and rectum, cervix uteri, and bladder.

[←] As shown in Table 1, 8 deaths from cancer of the liver during the period 1969-1978 were recorded in the state's mortality files. Examination of the corresponding medical records, however, indicated that 1 of these deaths had been incorrectly coded as liver cancer. Thus there were 7 deaths from liver cancer in Woburn in that time period.

For those cancer types that were elevated in at least one of the five-year periods, the cancer mortality patterns differ considerably. Cancers of other female organs were elevated in both five-year periods, but the excess was statistically significant only in the earlier period. Liver and kidney cancers were significantly elevated in 1974 - 1978, but only slightly elevated in 1969 - 1973. Leukemia was significantly elevated only in 1969 - 1973. Leukemia deaths actually decreased from eighteen deaths in the first period to twelve deaths in the second. Cancer of the bronchus and lung and cancer of the prostate were significantly elevated in the second period; in the earlier period, fewer deaths than expected from these causes occurred.

For causes of death other than cancer, significantly more deaths than expected occurred over the ten-year period from ischemic heart disease, cerebrovascular disease, and accidents. The mortality pattern for ischemic heart disease is similar for males and females and in both five-year time periods. Deaths from hypertension, non-malignant respiratory disease, and motor vehicle accidents were elevated in both time periods, but not significantly. Deaths from cirrhosis of the liver and diseases of the arteries were elevated for the ten-year period, which is accounted for by a significant excess of deaths from diseases of the arteries among females and from cirrhosis of the liver among males in the second period. Finally, fewer deaths than expected occurred from diabetes and suicide in 1969 - 1978.

Selected Mortality Profiles of Cities and Towns Surrounding Woburn

Six cities or towns are contiguous to Woburn: Burlington, Wilmington, Reading, Stoneham, Winchester, and Lexington. Their mortality experience for 1969 - 1978 was examined to determine the extent to which it was similar to Woburn's (Table 2). None of the towns showed a significant excess of deaths from cancer of the liver, kidney, bladder or leukemia.

Winchester is of particular interest, as it lies south of Woburn and the border it shares with Woburn is close to the residence area of several of the cases of childhood leukemia in Woburn. Moreover, the southerly flow of the Aberjona River and its watershed could conceivably transport contaminants from sections of Woburn to Winchester. Therefore, the residence at death of all Winchester residents who

died from leukemia, liver cancer or kidney cancer in the period 1969 - 1978 was analyzed to see if any unusual patterns were evident. No apparent concentration of deaths was seen in either the northern part of Winchester or in any other part of the town.

IV. METHODOLOGY

This study deals primarily with interviews of the renal cancer, liver cancer, and childhood leukemia cases, or a close relative. The analysis of these data is the main subject of this report. An investigation of bladder cancer incidence in Woburn is also reported on.

Case Definition

A case is defined as a person with confirmed renal cancer, liver cancer or childhood leukemia, who was diagnosed between 1969 and 1978 (1969 - 1979 for the leukemia cases), and who was a resident of Woburn at the time of diagnosis. Leukemia cases diagnosed after age 19 were not considered childhood leukemias.

Case Findings

Several sources were utilized in locating cases for inclusion in the study. All deaths of Woburn residents from renal cancer, cancer of the liver, or leukemia, which occurred in the period 1969 - 1978 were determined from the MDPH's computerized mortality data file. Incident cases of childhood leukemia were collected from Rev. Bruce Young of Woburn, Dr. John Truman of Massachusetts General Hospital, and two other major medical centers in Boston to which Woburn childhood leukemia patients are likely to be referred. Death certificates and the medical and pathology records from the referral centers and local hospitals were reviewed by a CDC physician, and the diagnoses verified. Date of diagnosis and cell type were determined. One referral center in Boston has a computerized tumor registry listing cases dating back over 20 years. This registry was used to search for additional cases, but none were found.

After the interview component of the present study had been completed, a local pathologist notified the MDPH that he had the impression that the annual number of bladder cancer specimens had increased in recent years. A review of pathology records at the two local hospitals primarily used by Woburn residents identified six additional cases of renal cancer and 29 cases of bladder cancer.

Interviews

The study questionnaire was developed, pretested, and revised by the MDPH and the CDC. The topics included in the questionnaire are summarized in Table 3. The majority of interviews were conducted by trained interviewers from the CDC and NIOSH during the week of June 23, 1980. Each interview took approximately 60 - 90 minutes. Informants were first contacted by phone by an employee of the MDPH, who explained the purpose of the study and requested an interview appointment. Participants signed a written consent form at the time of the interview, explaining the goals of the study, their right to refuse to participate, and the measures taken by the MDPH to insure the confidentiality of their responses.

Interviews were conducted with one or both parents of the 12 childhood leukemia cases. In addition, 2 age and sex-matched controls were interviewed for each of the leukemia cases. One control was a person of the same sex and age who lived close to the case; the other age and sex-matched control lived in a distant part of Woburn. A list of potential controls was selected by an employee in the office of the Woburn Superintendent of Schools from enrollment lists.

Interviews were conducted with the closest available relative of 17 deceased renal cancer cases; all 3 living renal cases known as of June 1980 were interviewed. No interviews were obtained for 4 deceased renal cancer cases either because of refusal (1) or because no next of kin could be located. As noted above, 6 additional renal cancer cases were identified after completion of the interview stage of the study.

Interviews were conducted with the closest available relative of 5 deceased liver cancer cases. Informants could not be located for the 2 other cases of liver cancer.

Analysis of the data was performed by the MDPH in consultation with the CDC. Reponses to all items on the study questionnaire were tabulated and analyzed. Only those items which resulted in some specific association or which concerned questions of relevance to the specific types of cancer included in the study are discussed in this report.

In the absence of cancer incidence data for Massachusetts, the Third National Cancer Survey (TNCS) data were used to calculate the expected number of cases for each of the diseases.[7] Demographic data for Woburn were obtained from the 1970 U.S. Census and the MDPH's official population estimates for 1975.[8] Geographical and residential analyses were done using Woburn census tract population data from the 1950, 1960, and 1970 U.S. Censuses.

V. RESULTS

A. Leukemia

The most important findings concerning childhood leukemia in Woburn are: (1) the incidence of childhood leukemia in Woburn was significantly elevated; (2) the excess leukemia cases were found primarily among males, not females; (3) there was a concentration of cases in the eastern part of Woburn. These findings and others are discussed in more detail below. The study produced no other positive findings about childhood leukemia.

A total of 17 childhood leukemia cases was originally found. Two were excluded because their date of diagnosis was prior to 1969, and 1 was excluded because, upon examination of medical records, it was found that the correct diagnosis was malignant lymphoma. One was excluded because the diagnosis of leukemia occurred prior to residence in Woburn, and another one was excluded because of residence in another town. Thus 12 cases of childhood leukemia were found in Woburn in the period 1969 - 1979.

Their clinical and demographic characteristics are presented in Table 4. All but 3 of the cases were acute lymphocytic leukemias. The 3 other diagnoses were: chronic myelocytic, acute monocytic, and acute myelocytic leukemia. All were diagnosed at or before 14 years of age. Eight of the 12 cases had lived in Woburn all their life. Two cases had lived in Woburn since the age of one. One case had moved to Woburn at age 7, four years prior to diagnosis. And one case moved to Woburn 4 months prior to diagnosis.

Childhood leukemia incidence in Woburn in the period 1969 - 1979 was significantly higher than expected: 12 cases were observed, 5.3 cases were expected, $p = .008$ (Table 5). This is accounted for by the elevated rate among males: 9 cases were observed, 3.1 cases were expected, $p = .005$ (Poisson distribution with parameter 3.1). Female leukemia rates were not elevated overall, although the 3 female cases were all diagnosed between the ages of ten and fourteen, a significant elevation for that single age group. The ratio of male to female is high, but not significantly so: $p = .12$ (Binomial distribution with parameters 12 and .57).

The dates of diagnosis of the cases are distributed rather uniformly over the 11-year period. Although 4 of the cases were born in the six-month period between December 1963 and May 1964, this also is not statistically significant; the probability is approximately .10 that at least 4 of the 12 cases would be born in some six-month period.[9]

An analysis of residence at the time of diagnosis of the leukemia cases shows a concentration of cases in the eastern part of Woburn, in particular in the area just north of Walker Pond. Map 2 displays Woburn's six census tracts, and the number of cases in each tract. Six cases resided within or on the border of census tract 3334, in an area approximately ½ mile in radius. There is a statistically significant concentration of cases in this census tract; the probability of 50% or more of the 12 cases occurring in this area, which contains only 17% of the town's 0 - 14 age group population, is less than .01 (Binomial distribution with parameters 12 and .17). The observed number of cases in this census tract is significantly higher than expected based on the TNCS, as shown in Table 6. Childhood leukemia

incidence for the rest of Woburn is not significantly elevated compared to national rates. The overall elevation for Woburn as a whole is accounted for primarily by the elevated rate in census tract 3334.

Childhood leukemia mortality, as distinguished from incidence, was not significantly elevated for the 1969 - 1978 period overall. Six childhood leukemia deaths occurred in this period, whereas 3.4 deaths were expected based on statewide statistics. But, 5 of the 6 deaths occurred between 1974 and 1978, which is significantly more than the 1.4 deaths expected, $p = .003$ (Poisson distribution with parameter 1.4).

Residence and the Environment

Residential patterns were basically stable among cases. Ten cases had lived at only one address and the others had each moved once to a location close to their former residence. Residences were also very stable among controls.

In the course of obtaining information on residential histories; case and control respondents were asked to comment on particular features of their residences, such as the quality of the drinking water; odors near the house; nearby construction; industries; streams and ponds; basement flooding; and any other features they deemed unusual.

The most frequent comments related to drinking water quality. The majority of both case and control respondents had one or more complaints regarding the drinking water (Table 7). Complaints were recorded about the odor, taste and color of the water, as well as about corrosion of plumbing fixtures and dishwashers, and discoloration of washed clothing. Although complaints were not limited to residents of one part of Woburn, they were more frequently voiced by residents of east Woburn (Table 8). Within east Woburn, however, cases did not differ from controls with respect to the rate and kinds of complaints about the water.

Complaints about airborne odors were also voiced by east Woburn residents. Of the 4 case and 4 control respondents with such complaints, only 1 lived outside east Woburn. Although in the past town-wide uniform mosquito spraying programs have been conducted, the occurrence of mosquito spraying was more frequently mentioned by case respondents.

School Histories

Elementary school-age children in Woburn generally attend school close to their homes. Of 5 school-age childhood leukemia cases residing in the Walker Pond area of Woburn, all attended one nearby elementary school. Four of these children, however, were diagnosed with leukemia prior to school age. Nearby construction, and the proximity of the school to Walker Pond, were the most frequent environmentally related comments made regarding this school. Although there were a few exceptions, the pattern of attending neighborhood schools also applied to both of the leukemia control groups. No other relationships or associations emerged between the cases and the controls and the schools they attended.

Family Medical History

Family medical histories were elicited from case and control respondents. There was not a great deal of difference between the case group and the two control groups. One of the few differences that did appear was a higher frequency of hypertension, diabetes and kidney disease among case families than among control families (Table 9). There was no reported leukemia among case relatives. Two grandparents of one close control had had leukemia. It was also reported that a relative of one other close control and a relative of each of three distant controls had had leukemia.

Pregnancies and Miscarriages

A similar proportion of mothers of cases and controls had had one or more miscarriages (Table 10). As a percentage of total pregnancies, the miscarriage rate is comparable for the case and control

groups. No significant geographic associations emerged except those due to the concentration of cases and their corresponding close controls, in east Woburn.

No significant differences were noted regarding pregnancy histories of the mothers of cases and controls. The mean age of mothers of cases at time of birth of the case was 26.8 years, compared to 28.4 years and 30.9 years for the mothers of close and distant controls respectively. Birth order distributions were similar among the three groups. None of the mothers of cases reported difficulty conceiving. One mother of a close control and three mothers of distant controls, however, did have difficulty conceiving. A small number of mothers in each group had had minor illnesses such as morning sickness during pregnancy, but no cases of influenza were reported. The only known exposure to x-rays consisted of two mothers of cases who had received dental x-rays during pregnancy. The only drugs taken by mothers of cases during pregnancy were vitamins except for two mothers who took antinausea compounds. Tobacco use and alcohol intake were low among all three groups of mothers. None of the mothers appear to have been exposed to occupational carcinogens during pregnancy. In summary, all of the mothers seem to have had healthy pregnancies, with essentially no known exposures to carcinogens or leukemogens.

Children's Medical History

For every childhood disease listed in the questionnaire, cases had a lower incidence than either group of controls. Three of the cases had received diagnostic x-rays for possible broken bones. The history of childhood immunizations was almost identical for the cases and the two groups of controls.

The cases' medical histories showed no associations with suspected carcinogenic, or, in particular, leukemogenic substances.

Parents' Occupation

The occupations of parents of cases and controls were found to be similar (Table 11), with no apparent association with known carcinogens. In addition, because exposure to carcinogens could potentially also result from working in specific areas of Woburn, attention was also given to the locations where parents worked. We found nothing suggestive, however, with regard to the location of the workplaces of the parents of the cases, nor any differences between parents of cases and controls.

Most of the fathers in each of the groups had served in the Armed Forces sometime prior to the conception of the cases or controls. As far as they knew, however, none of the fathers had been exposed to any suspect materials such as Agent Orange or intense radiation.

Environmental Exposures

Questions dealing with possible exposures in the home or neighborhood did not reveal any association with known or suspected carcinogens. Questions regarding gardening and consumption of garden produce showed no differences between cases and controls. Few cases or controls reported activities around the streams and ponds or known dumpsites in east Woburn. Few children in any of the groups had had contact with farm animals, had eaten meat or poultry raised at home, or had had unusual eating habits. Other activities such as jogging, walking or camping out were mentioned infrequently by any of the groups.

Only 1 or 2 of the cases had engaged in any one particular hobby, which is comparable to the controls. Parents reported that none of the cases and only one of the controls had engaged in activity that would bring them in contact with chemicals, fumes, or radiation. Most case and control families had had a household pet, usually a dog or a cat, but no unusual illnesses were reported among the pets.

Church Membership

A high portion of the families of the cases and the controls in Woburn were Roman Catholic, reflecting the high proportion of Catholics in Woburn in general. Eight cases and 22 control families were Roman Catholic. There were seven families of cases that reported regular church attendance, although they attended five different churches.

B. Renal Cancer

The most important findings concerning renal cancer are: (1) the incidence of renal cancer in Woburn was significantly elevated; (2) the excess incident cases of renal cancer had largely occurred among males; (3) there was a concentration of cases just east and northeast of Horn Pond.

Thirty cases of cancer of the kidney, including cancer of the ureter and the renal pelvis, were found in Woburn during the period of 1969 - 1978. As indicated above, interviews were completed for 20 of the 24 cases which were known as of June 1980. In addition, the 6 cases which were identified after the interviews had been completed are included in the calculations and analyses of rates and geographic locations of cases.

The overall incidence of renal cancer in Woburn was significantly higher than that expected based on the TNCS – 30 cases observed, 19.4 cases expected, $p < .05$. Although incidence was elevated for both sexes, the difference between observed and expected cases is statistically significant only for males – 20 cases observed, 12.0 cases expected, $p < .05$ (Table 13). Thirteen cases were diagnosed during 1969 - 1973 and 17 cases during 1974 - 1978.

Table 14 presents the age and sex distribution of the cases according to the age at diagnosis and compares it with the corresponding distribution of the TNCS. The age distribution for males is younger than for females in Woburn; it is also younger than both the male and female distributions reported by the TNCS. This is largely accounted for by the significant elevation in men diagnosed between the ages

of 50 and 54 – 7 cases observed, 1.3 expected, $p < .001$ (Poisson distribution with parameter 1.3). No significant elevations are found among particular female age groups. The ratio of male to female cases was only slightly higher than that found in the TNCS.

During the period 1969 through 1978, 24 cases of renal cell carcinoma, 5 cases of transitional cell carcinoma of the renal pelvis, and 1 case of transitional cell carcinoma of the ureter were diagnosed and ascertained by the procedures described above. Characteristics of these cases are summarized in Table 12. For purposes of analysis these three categories of renal cancer have been combined. Expected incidence has been computed from the combined incidence reported from the TNCS. The National Cancer Institute[10] reports the distribution of renal cancer by cell type in whites to be: Carcinoma NOS (Not Otherwise Specified) 5%, Transitional Cell 19%, Hypernephroma 56%, Adenocarcinoma NOS 9%, Wilm's 6%, All Other 4%. Assuming Carcinoma NOS, Hypernephroma and Adenocarcinoma NOS to be equivalent to renal cell carcinoma, then from the TNCS the ratio of renal cell to transitional cell carcinoma is 3.7. For the Woburn cases it is 4.8, a small and not statistically significant difference.

Mortality from renal cancer was significantly elevated in Woburn during the ten-year period 1969 -1978 (Table 1). Whereas 10.1 cases were expected based on the statewide experience, 19 cases were observed. This represents an 88% excess of renal cancer in Woburn over that which was expected. Both sexes had more deaths than expected; the difference is statistically significant, however, only for females. Renal cancer mortality was significantly elevated in the second five-year period – 4.9 cases expected, 11 cases observed – but only slightly elevated in the first period.

Residence

Information about place of residence at the time of diagnosis was available for all 30 identified cases. No apparent concentration of cases is evident when current residences are analyzed (Map 3). More complete residential histories were obtained for the twenty cases about whom interviews were conducted. For those cases not interviewed or who were identified subsequent to the interviews, residential histories were sought from the Woburn Poll Listings at Woburn's City Hall. Residence prior

to diagnosis was mapped for those cases for which information was available. This was done for five year intervals beginning at 15 years prior to diagnosis and extending to 30 years prior to diagnosis. Fifteen to 30 years prior to diagnosis is assumed to be the typical latent period[←] of cancer of the kidney.

The mapping revealed a concentration of cases in the area just east and northeast of Horn Pond at 20 years prior to diagnosis (Map 4). Of the 17 renal cancer cases who were known to live in Woburn at that time in their lives, seven resided within the border of census tract 3333, which comprised the area east and northeast of Horn Pond. Census figures for 1950 and 1960 reveal that approximately 15% of the total Woburn population resided in this census tract. Under the assumption that the 17 renal cancer cases are distributed according to the distribution of the population, the probability of finding 7 or more cases in census tract 3333 is .006 (Binomial distribution with parameters 17 and .15). Thus an unusual number of cases appear to have resided in that census tract.

Occupational Histories

Occupational histories were determined as part of the interviews because of the potential for exposure to known or suspected carcinogens in the workplace. Complete occupational histories were obtained for 20 of the cases (11 males and 9 females). Partial occupational histories from information recorded in the medical charts were obtained for the remainder (9 males and 1 female).

Table 15 lists those cases with possible occupational exposure to known carcinogens and/or lead. Ten of the males with complete histories might possibly have been exposed to known carcinogens, and all of them could possibly have been exposed to lead. Of the nine males with incomplete histories, two may have been exposed to known carcinogens and four to lead. Potential exposures in their workplaces were far fewer for women. It is difficult to evaluate these frequencies in the absence of occupational

[←] The latent period of a cancer is the interval between the first carcinogenic stimulus and the later appearance of a tumor. Different types of cancers may have different latent periods.

data from an appropriate comparison group or general town-wide information on the distribution of occupations.

Every male kidney cancer case worked for at least some period of his life in an occupation in which exposure to toxic chemicals was felt to be a tangible possibility. On the other hand, only two female respondents worked in such occupations. Both men and women had been employed in these occupations about 20 years prior to diagnosis, an important period considering the suspected latent period of renal cancer. The residences of those cases who were unlikely to have experienced occupational exposure were analyzed to see if any pattern emerged which suggested those cases were exposed to a non-occupational contaminant. No such patterns were apparent.

Environmental Exposures

Specific comments regarding problematic environmental features in or near their homes were considerably less common among respondents concerned with cancer of the kidney than among leukemia case and control respondents. About a third of the respondents had complaints about drinking water quality. A third of the respondents mentioned mosquito spraying in their neighborhood or the fact that they lived near a particular industry or factory, in most cases a leather or tanning factory. A smaller number of respondents commented on particular odors in their neighborhood.

Family gardening as well as consumption of garden produce was quite common among case families. Of the 15 families who had gardens, 7 respondents reported the use of pesticides or fertilizer, but none of the respondents knew what particular type of pesticide had been used. Fourteen of the fifteen respondents stated that the case had eaten garden produce regularly.

Five of 20 respondents stated that the family had had farm animals and 4 of these reported that the case had had regular contact with them. Only 2, however, reported that the animals had been sick. The

majority (14) of respondents reported having had household pets, usually a cat or dog. Five reported that the animal had been sick at some time; types of illnesses, however, varied.

Only a few cases apparently had had unusual eating habits (e.g. ate a lot of fresh fruit, ate dirt as a child) or had eaten pork or poultry raised at home. None had eaten fish caught in Woburn's lakes and streams and only two had fished regularly in those bodies of water.

Responses were almost all negative or unknown regarding activities around Woburn lakes, streams, other bodies of water and known dump sites. This may reflect the limited information respondents had regarding the cases' childhood and young adult activities.

No more than 3 respondents knew of a particular hobby or activity engaged in by the case, and only 2 respondents felt such an activity could have involved contact with chemicals, fumes, dust, or radiation. The most frequently reported exposure was to pesticides (7 cases), used in family gardens. The respondents had little knowledge about the cases' possible exposures to other toxic chemicals.

Fifteen of the cases regularly attended a church, but few were active in other community organizations. About a third of the cases were reported to have regularly traveled away from home.

Smoking History

Respondents reported that thirteen of the cases smoked; all but one smoked cigarettes. Of the 8 for whom information was available, 7 began smoking at an early age. Eight of the thirteen apparently quit smoking sometime before the onset of their illness.

Past Medical Histories of Cases

Most of the respondents did not know whether the case had had specific childhood infections (e.g. chicken pox, measles, etc.). Eight of the renal cases had had a tonsillectomy. The most frequently

mentioned illness was hypertension (5 cases). Other illnesses reported include kidney disease/stones (4 cases), another cancer (4 cases), and allergies (3 cases). Other serious diseases were less frequently mentioned and no patterns are evident.

Family Medical Histories

Family medical histories revealed no unusual frequency of specific diseases among case relatives. Cancer in immediate relatives was reported for 11 cases. Two cases had a positive family history of kidney cancer, and two were reported to have a family history of other types of kidney disease. Eight of the cases were reported to have immediate relatives with hypertension and six had a family history of diabetes.

C. Liver Cancer

The incidence of cancer of the liver in Woburn in the period 1969 – 1978 was only slightly higher than that expected from the TNCS and was not significantly elevated.

As indicated earlier, although ten deaths from liver cancer were reported on the official death certificates or hospital discharge forms, a detailed examination of the medical records revealed that one person actually had cancer of the pancreas, one had cancer of the gallbladder, and one had a metastatic cancer of the liver, with unknown primary site. Thus, seven cases of cancer of the liver occurred in Woburn during 1969 – 1978; interviews were completed for five of these cases (Table 16).

Based on incidence data from the Third National Cancer Survey, 6.4 cases would have been expected. Thus the incidence of liver cancer among Woburn residents was not significantly elevated compared to nationwide norms. Of the 7 cases, 4 were males and 3 were females. The expected numbers based on the TNCS are 3.9 cases among males and 2.5 among females. Date of diagnosis did not tend to cluster in any particular time period. Analysis of residence at time of diagnosis revealed no apparent clustering of cases (Map 5).

Mortality from liver cancer was significantly elevated among Woburn residents compared to statewide norms, in the period 1969 – 1978. Whereas 3.2 deaths were expected, 7 deaths were observed.[11] In the period 1969 – 1973, 3 deaths were observed, whereas 1.8 were expected. In the period 1974 – 1978, there was a significant excess of deaths from liver cancer, primarily accounted for by an excess among females (.4 cases expected, 3 cases observed, $p < .05$ (Poisson distribution with parameter .4).

D. Bladder Cancer

The close functional relationship between the kidney and the bladder, and the suggestion by a local pathologist that bladder cancer may be elevated in Woburn prompted an additional investigation of bladder cancer mortality and incidence.

Bladder cancer mortality was not elevated in Woburn in the ten-year period 1969 – 1979, 14.5 cases expected, 13 cases observed – not for either of the two 5-year periods. There were fewer deaths than expected for males, 9.6 deaths expected, 5 deaths observed, and more deaths than expected for females, 4.9 expected, 8 observed. This difference, however, is not statistically significant.

Using case finding procedures similar to those used for identifying the other cancer cases, 29 cases of bladder cancer were identified who were diagnosed between 1969 and 1978. Twenty were males and 9 were females (Table 17). Based on TNCS incidence rates, 45.9 cases were expected but only 29 cases were observed, a difference which is statistically significant. For both males and females the observed number of cases was lower than expected; this was true particularly for males - 33.3 cases expected, 20 observed ($p < .+05$). These rates are consistent with the mortality findings. Based on residence at time of diagnosis, there was no apparent geographical concentration of cases.

VI. ENVIRONMENTAL DATA

This section of this report is a brief summary of available environmental data concerning Woburn. At the start of this investigation, much attention was focused on hazardous waste sites in Woburn. In July 1979, Environmental Protection Agency (EPA) field investigators discovered an abandoned lagoon, 34,918 square feet in area and up to five feet deep, contaminated with lead and arsenic. Arsenic was found in concentrations as high as 1050 parts per million.[2] It is not known for certain, but it is likely that the arsenic was deposited between 1899 and 1914. Engineers demonstrated that arsenic has leached into a nearby pond. Other wastes found in nearby areas are shown in Table 19. In addition to these chemicals, pits of buried animal hides and slaughterhouse wastes were discovered during site preparation operations for the industrial park. These wastes are believed to be responsible for much of the foul odor that residents frequently complain about.

Woburn's water supply has been tested several times for contamination. Wells G and H proved to contain pollutants. Tests of all other Woburn wells have consistently shown them to meet the interim federal drinking water standards. Well G began to pump in 1964 and Well H in 1967.[12] Well G was on line until early 1967, and from then to May 1979 was on and off depending on the water needs of the city. Well H, which started pumping in July 1967, was shut down in December of that year and remained shut down until August 1974. From then until May 1979, when both G and H were permanently shut down as a result of the discovery of organic contaminants (Table 20), the well was also periodically on and off depending on the city's needs. Although these wells were originally planned as a supplemental source of Woburn's water needs, records indicate that a considerable amount of water was pumped from them when they were on line. Because of the water distribution system, some of the water from G and H reached most parts of Woburn. The area primarily serviced by these wells, however, was the eastern section of Woburn (Map 6). Tests for arsenic, chromium and lead in 1979 demonstrated no detectable chromium and lead, and very low levels of arsenic in Wells G and H (Table 20), in conformance with interim federal drinking water standards.

We have no information indicating types and levels of contaminants, if any, in Wells G and H prior to May 1979. Recent static testing of Well G for the 129 chemicals included on EPA's Priority Pollutant List revealed no new contaminants but did confirm the presence at similar concentrations of the organics found previously (Table 21). It is important to note that extensive testing of all other Woburn wells showed the water meets state and federal drinking water standards.

Air Quality Data

Little air quality data are presently available. A study done in 1977 measured hydrogen sulfide and sulfur dioxide concentrations at various locations within and close to the Industri-Plex site and in nearby Reading. Areas downwind of the construction site experienced hydrogen sulfide concentrations 10 to 100 times the odor threshold, which may induce headaches, bronchitis, nervous system disorders and eye irritation in susceptible individuals.[13] As reported by the Massachusetts Department of Environmental Quality Engineering, tests for arsenic gas and dust in 1979 found none in the area of the dump site.

DISCUSSION

A. Leukemia

This investigation has established that, during the years 1969 – 1979, there was a significantly elevated incidence of childhood leukemia in Woburn. For males, the incidence in the eastern part of Woburn was 12.5 times that expected as calculated from TNCS incidence data. The male to female ratio was 3, slightly more than double that reported by the TNCS, which was 1.4 for whites age 0 – 14. The age distribution among females is unusual in that all three cases were between the ages of 10 and 14 at the time of diagnosis. Excess acute lymphocytic leukemia is known to occur among cohorts of children born following influenza epidemics.[14] Four cases were born in a six-month period, but no influenza was reported by the mothers.

Several previous investigations into possible leukemia clusters have found that the leukemia cases involved were predominantly Catholic and were members of the same parish or the same church.[15] While the families of the leukemia cases in this study were primarily Catholic, the possibility of an association through church membership seems to be ruled out by the number of different churches the families attended.

The case control study failed to identify any factor that significantly distinguished the cases from the controls. This is not altogether surprising, for, with few exceptions, investigations of leukemia clusters have failed to demonstrate significant associations or even promising leads as to possible environmental causes.[15,16]

Approximately three miles north of the area of concentration of the leukemia cases is the Industri-Plex site, in which, as described above, hazardous waste dumps have recently been uncovered containing such toxic heavy metals as lead, arsenic, and chromium (Table 19). The Aberjona River flows through this site and its watershed flows south through the area where the leukemia cases reside. The wastes have been present at the site for a number of years, but these heavy metals are insoluble in water and are therefore not easily transported. In fact, testing of Wells G and H, which are located about a one-half mile north of the leukemia case concentration area, indicated no lead or chromium. Arsenic was found at levels considerably below the official drinking water standard.

Although chromium and arsenic are known carcinogens, they have not been demonstrated to be leukemogenic.[17,18] While lead is quite toxic, affecting the kidneys and central nervous system as well as other organs, it is not known to cause leukemia.[19] Further, this study indicates that the leukemia cases and their immediate families had little, if any, physical contact with the site. Four of the six cases in the area of concentration were diagnosed before age seven and none of the parents responded that their children played near or on the dumpsite.

Possibly of more relevance to the leukemia concentration is the contamination of Wells G and H. Well G was on line during the probable critical exposure period for the leukemia cases some time prior to diagnosis, which for most of these children was the mid to late 1960s. As far as we have been able to determine, environmental data do not exist prior to 1979 that would give us any indication of what, if any, contaminants existed in Wells G and H in the past.

The interview responses indicate that water quality complaints among residents of the eastern section of Woburn were not just of recent origin, but were voiced by residents who lived in the area in the 1960s through the late 1970s. These subjective complaints, however, cannot be correlated with the presence of specific contaminants. None of the chemicals found in Wells G and H are known to be leukemogenic, although chloroform,[20] trichloroethylene[21] and tetrachloroethylene[22] have been found to cause tumors in laboratory animals. Even if a known leukemogen such as benzene[23,24] were currently found in the wells it would still be necessary to establish that it was present and that a specific exposure occurred sometime prior to the diagnosis of the disease. The lack of environmental data for earlier periods is a major obstacle in trying to establish a link between environmental variables and the health effects identified in Woburn.

It is important to stress that the contaminants found in Wells G and H are not known to cause leukemia. Yet the fact that organic contaminants were found at all in the water supply must also be emphasized. The source of the present contaminants is unknown.

B. Renal Cancer

The incidence of renal carcinoma was higher than that expected on the basis of the TNCS, in both sexes, but significantly so only in males. It was particularly elevated in males younger than 55 - 9 observed, 2.5 expected. The age distribution for males was younger than for females, and younger than for both males and females in the TNCS. A recent Connecticut study of renal cancer found a birth cohort effect for men only, with incidence rates increasing as the year of birth became more recent.[25] The observed age distribution in Woburn suggests that such may have also be the case here.

The interviews of next of kin or of cases revealed no particularly strong associations. Reasonably detailed data on occupation were obtained, but no clear pattern emerged. A number of occupations involved some potential lead exposure, interesting because lead workers have been found to have impaired renal functions,[26] and because kidney cancer has been produced in laboratory animals by lead ingestions.[27]

Interest in renal cancer in Woburn was stimulated in part by a report of an apparent excess of renal cancer among former workers at a pet food processing plant located near an identified dumpsite. None of the cases of renal cancer we studied had a history of working in this plant.

There is some suggestion of residential concentration of cases 20 years prior to diagnosis in the area east and northeast of Horn Pond. A significantly greater proportion of cases resided in this census tract than would have been expected based on the distribution of the city's population. No environmental or historical data exist to investigate what environmental or health hazards, if any, were associated with this area.

C. Liver Cancer

The apparent elevation of incidence of cancer of the liver turned out to be an artifact, as examination of the clinical records revealed that several deaths had been erroneously coded as liver cancer.

D. Bladder Cancer

Bladder cancer incidence was examined because a local pathologist reported a recent increase and because of its functional relationship to the kidney and ureter. There actually has been an increase in incidence, from 10 cases diagnosed in 1969 – 1973 to 19 cases in 1974 – 1978. Despite this increase, the observed incidence of bladder cancer was lower than expected from the TNCS incidence data. Further, the age-specific rates for ages 45 – 74 were very close to those observed in eastern

Massachusetts by Cole and his associates.[28] The major reason for the observed number of cases being lower than expected in Woburn is that no cases of bladder cancer were observed in males older than 74, the group in which high rates are usually found. This deficiency may be due to competing causes of death. Although in one study[29] Cole estimated the risk of bladder cancer in male leather workers to be over double that expected, and five of the bladder cancer cases worked in the leather industry, we lack the necessary information to determine if this is higher than expected.

Even though a great deal of environmental testing has been performed in Woburn over the past year and a half, two facts point out the limited usefulness of this information in assessing the health effects of enviornmental hazards in Woburn:

1. Until recently most attention and environmental sampling has focused on the Industri-Plex area of Woburn where major dumpsites of toxic waste products have been uncovered. Only recently has much attention been paid to the area south of Route 128 and, in particular, the area of leukemia case concentration, and even less environmental data are available for other parts of Woburn (e.g. the area around Horn Pond).
2. In addition, the environmental data that have been collected reflect current types and levels of contamination. The critical exposure period for the cancers studied, however, is likely to be a number of years prior to diagnosis. In the case of renal cancer, environmental exposures 15 – 30 years prior to onset of the disease are likely to be most relevant in assessing the possible association between environmental factors and disease. Determination of exposures in the 1960s and early 1970s would be most helpful in the investigation of childhood leukemia.

VII. CONCLUSIONS AND RECOMMENDATIONS

This investigation has established that in the period under investigation, the overall incidence of childhood leukemia was significantly elevated in Woburn and, in particular, in the eastern section of Woburn. The incidence of renal cancer is also significantly elevated in that period.

Information gathered thus far fails to establish any association between environmental hazards and increased incidence of childhood leukemia and renal cancer in Woburn. The hypothesis suggesting that the increase in leukemia incidence was associated with environmental hazards in Woburn and specifically to the contamination of drinking water supplies is neither supported nor refuted by the study findings. Interviews with parents of leukemia cases, two groups of matched controls, and family members of renal cancer cases revealed no associations between any environmental factors and disease. Further investigation of this possible association should include the following:

- Attempt to ascertain childhood leukemia mortality and incidence in Woburn prior to 1969, i.e. in the 1950s and 1960s. Finding that childhood leukemia became elevated in the eastern part of Woburn only after Wells G and H came on line would support the hypothesis that the elevated leukemia incidence was related to drinking water contaminants.
- Determine the incidence of other lymphatic disease in Woburn to see if it follows a pattern similar to childhood leukemia over the same time period.
- More generally, determine the incidence of other types of cancer in Woburn prior to 1969.
- Environmental agencies are continuing to attempt to identify the present source of organic contaminants in Wells G and H. This information may help identify past practices of waste disposal and sources of contaminants.

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ATTENTION:

TABLE 1: Massachusetts Mortality Profiles For Selected Causes: 1969-1978- Woburn

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TABLE 2

SELECTED MORTALITY PROFILE FOR TOWNS CONTIGUOUS WITH WOBURN-BOTH SEXES, 1969-1978

CITY/ TOWN		ALL DEATHS	ALL CANCERS	LIVER CANCER	KIDNEY CANCER	BLADDER CANCER	LEUKEMIA
Burlington	**OBS**	96.3	202	1	4	3	8
	EXP	945.0	192.8	1.2	3.6	4.0	8.7
	SMR	102	105	83	11.1	75	92
Wilmington	**OBS**	1029	219	0	1	3	8
	EXP	1017.7	208.1	1.1	3.7	5.0	8.4
	SMR	101	105	0	27	60	95
Reading	**OBS**	1722	354	3	6	10	14
	EXP	1869.3	386.6	2.2	7.1	9.6	14.1
	SMR	92^{--}	92	136	85	104	99
Stoneham	**OBS**	1800	433	3	8	11	15
	EXP	1850.9	391.5	2.2	7.1	9.9	13.8
	SMR	97	111^{+}	136	113	111	109
Winchester	**OBS**	1637	350	2	11	9	15
	EXP	2002.7	417.8	2.4	7.6	10.8	14.8
	SMR	82^{--}	84^{--}	83	145	83	101
Lexington	**OBS**	2202	509	4	11	11	23
	EXP	2452.6	510.1	3.0	9.2	12.7	18.7
	SMR	90^{--}	100	133	120	87	123
Woburn	**OBS**	2944	627	8	19	13	30
	EXP	2737.7	554.0	3.2	10.1	14.5	21.0
	SMR	108^{++}	113^{+}	250^{+}	188^{++}	90	143

$^{+}$or $^{-}$ indicates a statistically significant elevation or deficiency at .05 level

$^{++}$ or $^{-}$ indicates a statistically significant elevation or deficiency at .01 level

TABLE 3

VARIABLES INVESTIGATED IN THE INTERVIEWS

Demographic Information Sex Place and date of birth Ethnic background Religious background	**Family Background and Medical History** **Smoking History**
Disease Process Age and date of diagnosis Age and date of death Time of onset of symptoms Description of course of illness Treatment	**Residential History** **School History***
Past Medical History History and description of specific illnesses Diseases prior to onset Birth defects Medical procedures -immunizations -transfusions -tonsillectomy -x-ray	**Occupational History** **Occupational History of Family Members** **Environmental Exposures** Gardening Activities in Woburn lakes/streams Contact with farm animals Eating habits Activities near dumpsites/ open bodies of water in Woburn Hobbies Exposure to hairspray/ hairdye Household pets Church and community activities Travel outside Woburn Military service Exposure to specific chemicals
Immunization History*	
Pregnancy History* Number pregnancies, deliveries, miscarriages Age of mother and father Birth order Mother's history of illness, personal activities, exposures during case pregnancy Father's military history Father's exposures prior to case pregnancy Pregnancy outcome Occupational exposures of mother during pregnancy	

***Asked only of leukemia case and control respondents**

TABLE 4

CHARACTERISTICS OF WOBURN CHILDHOOD LEUKEMIA* CASES

Case #	Sex	Date of Birth	Date of Diagnosis	Age at Diagnosis (years)	Status	Length of Woburn Residence Prior to Diagnosis (years)
1	M	7/68	1/72	3	ALIVE	3
2	M	12/63	3/78	14	ALIVE	14
3	M	10/70	6/73	2	ALIVE	2
4	M	3/72	10/76	4	ALIVE	4
5	M	6/69	8/79	10	ALIVE	10
6	F	4/64	12/75	11	ALIVE	10
7	F	12/63	8/76	12	DIED (2/78)	12
8	M	3/75	9/75	1	DIED (11/75)	<1
9	M	5/64	11/69	5	DIED (3/80)	<1
10	F	4/58	3/69	11	DIED (7/70)	4
11	M	9/65	7/74	8	DIED (6/77)	8
12	M	6/65	7/71	6	DIED (2/74)	6

***All cases are Acute Lymphocytic Leukemia except Case # 5- Chronic Myelocytic Leukemia, Case #6- Acute Monocytic Leukemia, and Case # 8- Acute Myelocytic Leukemia.**

TABLE 5

COMPARISON OF OBSERVED NUMBER OF CHILDHOOD LEUKEMIA CASES IN WOBURN, 1969-1979, TO EXPECTED CASES BASED ON TNCS*

Sex	Age Group	1970 Pop. Woburn	Observed # Cases	Expected # Cases	Ratio: Observed/ Expected	P value
MALES	0-4	1784	4	1.4	2.8	.054
	5-9	2057	3	.9	3.3	.063
	10-14	2128	2	.7	2.8	.156
	ALL AGES (0-14)	5969	9	3.1	2.9	.005
FEMALES	0-4	1714	0	1.3	----------	1.000
	5-9	19821	0	.5	----------	1.000
	10-14	2083	3	.4	7.5	.008
	ALL AGES (0-14)	5779	3	2.2	1.4	.377
BOTH SEXES	0-4	3498	4	2.7	1.5	.286
	5-9	4039	3	1.4	2.1	.167
	10-14	4211	5	1.1	4.5	.005
	ALL AGES (0-14)	11748	12	5.3	2.3	.008

- **Third National Cancer Survey, 1969-1971, Whites, All Areas Combined.**

TABLE 6

COMPARISON OF OBSERVED NUMBER TO EXPECTED* NUMBER OF CHILDHOOD LEUKEMIA CASES IN WOBURN BY CENSUS TRACT, 1969-1979

	Woburn Pop. 1970	**Observed # Cases**	**Expected # Cases**	**Ratio Observed/ Expected**	**P-Value**
Both Sexes, Ages 0-14					
Census Tract 3334	1707	6	.8	7.5	<.001
All other Woburn Census Tracts	10041	6	4.5	1.3	.297
Males, Ages 0-14					
Census Tract 3334	884	5	.4	12.5	<.001
All other Woburn Census Tracts	5085	4	2.6	1.5	.264

***Expected based on Third National Cancer Survey, 1969-1971.**

TABLE 7

SUMMARY OF DRINKING WATER COMPLAINTS OF LEUKEMIA CASE AND CONTROL RESPONDENTS

Respondent Category

Nature of Complaint	**Cases (N=12)**	**Close Controls (N=12)**	**Distant Controls (N=12)**
Complaint about any aspect of drinking water			
	9	11	7
Categories of complaint about drinking water:			
Odor	8	5	3
Taste	4	2	4
Color	7	6	5
Corrosion of Fixtures/Dishwasher	1	3	2

TABLE 8

SUMMARY OF DRINKING WATER COMPLAINTS BY RESIDENCE OF RESPONDENT

	East Woburn Residents		**Other Woburn Residents**	
Nature of Complaint	**Cases (N=7)**	**Controls (N=7)**	**Cases (N=5)**	**Controls (N=17)**
Complaint about any aspect of drinking water				
	6	6	3	8
Categories of complaint about drinking water:				
Odor	6	3	2	5
Taste	3	3	1	1
Color	6	3	1	8
Corrosion of fixtures/dishwasher	1	3	0	2

TABLE 9

FREQUENCY OF HYPERTENSION, DIABETES, AND KIDNEY DISEASE AMONG RELATIVES OF LEUKEMIA CASES AND CONTROLS

		Immediate Family*	Grandparents	Distant Relatives
Hypertension Alone	Cases	2	9	4
	Close Controls**	4	6	2
	Distant Controls	3	3	2
Hypertension and Diabetes or Kidney Disease	Cases	3	2	0
	Close Controls	0	2	0
	Distant Controls	0	1	0
Diabetes	Cases	2	8	4
	Close Controls	0	5	3
	Distant Controls	0	6	2
Kidney Disease	Cases	3	2	5
	Close Controls	1	0	2
	Distant Controls	4	2	2
Leukemia	Cases	0	0	0
	Close Controls	0	2	1
	Distant Controls	0	0	3

***Includes parents and siblings.**

**** One close control was adopted; no family medical history was included.**

TABLE 10

MISCARRIAGES AMONG MOTHERS OF LEUKEMIA CASES AND CONTROLS

	Cases (N=12)	**Close Controls (N=11)**	**Distant Controls (N=12)**
Total # of pregnancies	55	54	58
Total # of mother who had one or more miscarriages	5	5	4
Number of miscarriages 1	4	2	2
2	0	0	1
3	1	3	0
4	0	0	1
Total # of Miscarriages	7	11	3
Percentage of pregnancies resulting in miscarriage	13	20	14

*** Excludes one adoptive mother with no pregnancies.**

TABLE 11

OCCUPATIONS OF PARENTS OF LEUKEMIA CASES AND CONTROLS

	Occupation	Cases (N=12)*	Close Controls (N=12)	Distant Controls (N=12)
Father	Supervisor/Manager (White collar)	3	2	1
	Construction	1	2	1
	Postal Clerk/Carrier	0	1	2
	Electronics	0	2	1
	Truck Driver	0	1	2
	Laborer	0	1	1
	Fireman/Policeman	1	1	1
	Sheet metal Worker/ Welder	2	1	0
	Sales/Clerical	2	1	0
	Lab Technician	1	0	1
	Other**	5	3	2
Mother	Clerical	5	2	5
	Banking	3	0	0
	Nurse/Nurses' Aide	2	1	1
	Other**	0	3	0

***Some parents had more than one occupation**

****Includes occupations mentioned only once**

TABLE 12

CHARACTERISTICS OF WOBURN RENAL CANCER CASES

	Sex	Age at Diagnosis	Month and Year of Diagnosis
Cancer of Kidney	M	67	3/69
	F	53	9/69
	F	67	8/70
	M	46	12/70
	F	77	1/71
	M	61	1/71
	M	69	5/73
	M	52	7/73
	M	51	5/74
	M	58	12/74
	M	62	7/75
	F	66	10/75
	F	62	3/76
	M	50	6/76
	F	62	5/77
	M	51	7/77
	M	75	11/77
	F	58	3/78
	M	49	5/78
	M	59	6/78
	F	74	7/78
	F	23	9/78
	M	69	12/78
	M	54	12/73
Cancer of Kidney, Pelvis	M	78	5/69
	M	54	2/70
	M	68	3/70
	M	54	9/70
	F	63	1/78
Cancer of Ureter	M	78	4/72

TABLE 13

COMPARISON OF OBSERVED INCIDENCE OF RENAL CANCERS IN WOBURN, 1969-1978 TO EXPECTED INCIDENCE BASED ON TNCS*, 1969-1971

Groups	**Woburn Population 1970**	**Expected # Of Cases**	**Observed # Of Cases**	**Ratio Observed/ Expected cases**	**P Value**
Males	17939	12.0	20	1.7	<.05
Females	19128	7.4	10	1.4	Not. Sign.
Total	**37067**	**19.4**	**30**	**1.5**	**<.05**

*** Based on Third National Cancer Survey, 1969-1971.**

TABLE 14

OBSERVED AND EXPECTED AGE AND SEX DISTRIBUTION FOR RENAL CANCER CASES

Sex	**Males**				**Females**			
	Woburn		**TNCS**		**Woburn**		**TNCS**	
Age at Diagnosis	**Obs**	**Cum. %**	**Exp**	**Cum %**	**Obs**	**Cum. %**	**Exp**	**Cum. %**
0-19	0	0	.52	4.3	0	0	.47	6.4
20-24	0	0	.02	4.5	1	10	.05	7.0
25-29	0	0	.05	4.9	0	10	.04	7.6
30-34	0	0	.09	5.7	0	10	.05	8.2
35-39	0	0	.25	7.7	0	10	.17	10.5
40-44	0	0	.48	11.7	0	10	.34	15.1
45-49	2	10	1.20	21.7	0	10	.43	20.9
50-54	7	45	1.33	32.8	1	20	.67	30.0
55-59	2	55	1.35	44.0	1	30	.83	41.2
60-64	2	65	1.73	58.4	3	60	.82	52.3
65-69	4	35	1.59	71.7	2	80	.87	64.0
70-74	0	85	1.22	81.8	1	90	.98	77.3`
75-79	3	100	1.16	91.5	1	100	.69	86.6
80-84	0	100	.59	96.4	0	100	.60	94.7
85+	0	100	.43	100.0	0	100	.39	100.0
TOTAL	**20**		**12.01**		**10**		**7.40**	
Median Age at Diagnosis	58.5				62.5			

TABLE 15

OCCUPATIONS OF RENAL CANCER CASES WITH POTENTIAL EXPOSURE TO LEAD AND KNOWN CARCINOGENS

Sex	Occupations with Potential Exposure to Lead	Occupations with Potential Exposure to Carcinogens
M	Bricklayer Electronics worker	Shipyard worker
M	Printer	Printer
M	Postal Carrier Foundry worker	Furniture worker
M	Leather Worker	Leather Worker
M	Motor vehicle inspector Leather worker	Maintenance worker Leather worker
M	Leather worker	Leather worker
M	Gas station attendant Welder	Welder
M	Leather Worker	Maintenance worker
M	Gas station attendant	
M	Fishery (canning)	Carpenter Maintenance worker
M	Welder	Welder
M	Farm work/greenskeeper	
M	Farm work	
M	Leather Worker	Leather worker
M	Painter	Painter
F		Paper box manufacturing
F		Glue machine operator
F	Farm Work	

1. National Institutes for Occupational Safety and Health (NIOSH), CDC "To the Work-Relatedness of Disease, Revised Edition". Kusnetz, S. Editors, 1979.

TABLE 16

CHARACTERISTICS OF WOBURN LIVER CANCER CASES

Sex	Age at Diagnosis	Month and Year of Diagnosis
M	81	6/72
M	60	11/73
F	59	1/74
F	81	11/74
F	79	6/75
M	55	3/77
M	46	3/78

TABLE 17

CHARACTERISTICS OF WOBURN BLADDER CANCER CASES

Sex	Age at Diagnosis	Month and Year of Diagnosis
F	64	4/69
F	62	10/69
M	64	1/70
M	68	3/70
M	50	6/70
M	62	12/71
M	48	8/72
M	73	2/72
M	19	1/73
F	85	8/73
M	47	1/74
M	65	5/74
M	60	10/74
F	65	4/75
M	60	6/75
M	51	9/75
F	54	10/75
M	56	11/75
M	69	2/76
M	51	8/76
F	62	12/76
M	49	12/76
M	72	4/77
F	73	12/77
M	69	2/78
M	72	2/78
F	66	3/78
F	77	7/78
M	73	10/78

TABLE 18

OBSERVED AND EXPECTED AGE AND SEX DISTRIBUTION FOR WOBURN BLADDER CANCER CASES

AGE GROUP	MALES				FEMALES			
	Woburn		TNCS		Woburn		TNCS	
	OBS	Cum %	EXP	Cum %	OBS	Cum %	EXP	Cum %
0-19	1	5	.10	0	0	0	.06	0
20-24	0	5	.12	1	0	0	.02	1
25-29	0	5	.13	1	0	0	.05	1
30-34	0	5	.21	2	0	0	.08	2
35-39	0	5	.36	3	0	0	.16	3
40-44	0	5	.92	6	0	0	.26	5
45-49	3	20	1.70	11	0	0	.46	9
50-54	3	35	2.46	18	1	11	.80	15
55-59	1	40	3.15	27	0	11	1.20	25
60-64	4	60	4.66	41	3	44	1.28	35
65-64	4	80	5.11	57	2	67	1.47	46
70-74	4	100	5.14	72	1	78	1.95	62
75-79	0	100	4.72	86	1	89	1.87	77
80-84	0	100	2.76	95	0	89	1.72	91
85+	0	100	1.77	100	1	100	1.17	100
TOTAL	20		33.31		9		12.55	

TABLE 19

TYPES AND CONCENTRATIONS OF METALS FOUND IN INDUSTRIPLEX SITE[1]

Metal	Samples (ppm)				Normal Soil
	A	B	C	D	Concentrations[2]
Iron	257,000	42,900	418,600	5,800	15,000
Manganese	15,800	169	119	17	285
Copper	84	32	1,690	38	14
Lead	287	99	229	811	14
Zinc	227	129	1,990	57	36
Chromium	386	33	7	36	36
Cadmium	0	11	7	0	-
Nickel	339	21	14	14	13
Tin	920	1,990	1,590	255	-
Calcium	19,800	199,800	299	2,070	3,200
Magnesium	1,380	2,490	100	151	-
Sodium	25,700	14,980	428	255	2,600
Aluminum	85,000	55,900	830	26,400	33,000
Arsenic	110	200	1,050	880	6

[1] Soil samples 9/24/79 at 128 Commerce Way, Woburn.

[2] Department of Environmental Quality Engineering. Special Analysis—Samples of Waste Deposits—D'Annolfo's Commerce Way, Woburn. Contained in memo from Robert Cleary, DEQE, to Richard Chalpin, DEQE, dated October 24, 1979.

TABLE 20

CONTAMINANTS IN WELLS G & H, WOBURN, MASSACHUSETTS, 1979

Organics	Well G			Well H		
	5/14	7/24	9/24	5/14	7/24	9/24
Chloroform	11.8[2]	-	1.1	ND[3]	-	ND
Trichloroethylene	267.4	-	117.6	183.6	-	63.0
Tetrachloroethylene	20.8	-	18.3	13.4	-	9.0
1,1,1-tetrachloroethane	0.6	-	ND	ND	-	2.1
Dibromochloromethane	2.0	-	ND	ND	-	ND
Trichlorotrifluoroethane[4] (Freon)		22 ppb			23 ppb	
Dichloroethylene[4]		28 ppb			ND	
Dichlorotrifluoroethane[4]		<5 ppb			ND	
Metals						
Arsenic		0.0020 ppm[5]			0.0015 ppm	
Chromium		ND			ND	
Lead		ND			ND	

1. Special Analysis – Woburn. Water samples taken from wells G and H by McCall, DEQE (5/14/79), and Erickson, DEQE (9/24/79)
2. Micrograms per liter or parts per billion (ppb)
3. ND – None Detectable
4. Analysis for Volatile Organics, on Woburn wells G and H. Results contained in memorandum from R. Siscanaw, EPA, to E. Taylor, EPA
5. Milligrams per liter or parts per million (ppm)

ATTENTION:

TABLE 21: Well G Test Results for E.P.A.'s Priority Pollutants
MAP 1: Woburn and Surrounding Communities
MAP 2: Residence at Diagnosis of Childhood Leukemia Cases
MAP 3: Residence at Diagnosis of Woburn Renal Cancer Cases
MAP 4: Residence of Renal Cancer Cases 20 Years Prior to Diagnosis
MAP 5: Residence at Diagnosis of Woburn Liver Cancer Cases
MAP 6: Location of Woburn's Wells and Area Serviced by Wells G and H

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