Case-control Study of Childhood Cancers in Dover Township (Ocean County), New Jersey

Volume I: Summary of the Final Technical Report

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Division of Epidemiology, Environmental and Occupational Health
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U.S. Department of Health and Human Services

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Introduction

In 1995, at the request of the federal Agency for Toxic Substances and Disease Registry (ATSDR), the New Jersey Department of Health and Senior Services (NJDHSS) evaluated the occurrence of childhood cancer in Dover Township and found that the incidence was significantly higher than expected for the period 1979 through 1991. Consequently, the NJDHSS and ATSDR, in cooperation with the local Citizen Action Committee for Childhood Cancer Cluster, developed a Public Health Response Plan (PHRP) detailing a systematic process to investigate the elevation of childhood cancer in Dover Township. The PHRP's purpose was twofold: 1) to update and re-evaluate information on childhood cancer incidence in Dover Township; and 2) to evaluate possible community exposures to toxic chemicals in the environment, called exposure pathways, in order to generate hypotheses which could be assessed in an epidemiologic study.

The results of the cancer update, *Childhood Cancer Incidence Health Consultation: A Review and Analysis of Cancer Registry Data, 1979-1995 for Dover Township (Ocean County), New Jersey* (1997), confirmed that the overall childhood cancer incidence rate in Dover Township was statistically significantly elevated for the period 1979 through 1995, primarily due to excesses of leukemia (over 9 times higher than expected) and brain and central nervous system cancer (11.5 times higher than expected) in females under age five residing in the Toms River section of the Township.

Findings of the PHRP evaluation of potential exposure pathways in the community indicated that past releases of toxic chemicals into the environment had resulted in exposure to residents in Dover Township. Consequently, NJDHSS and ATSDR concluded that the Reich Farm Superfund site was a public health hazard due to past human exposures to toxic chemicals due to groundwater contamination which affected both private wells and wells in the public water distribution system. Early in the course of evaluating these exposure pathways, testing of the community water supply revealed a previously undiscovered contaminant, styrene-acrylonitrile (SAN)

trimer, attributable to the Reich Farm site, in groundwater from two of the wells in the United Water Toms River (UWTR) Parkway well field. NJDHSS and ATSDR also concluded that the Ciba-Geigy Corporation Superfund site represented a public health hazard due to past human exposures to toxic chemicals from operations at the facility, through past groundwater contamination affecting public water wells and private wells used for irrigation. Past air pollution emissions from the facility were also of public health concern.

In 1997, based on these findings, NJDHSS and ATSDR decided to conduct an epidemiologic study to evaluate the relationship between the completed environmental exposure pathways and the elevated childhood cancer incidence in this community. The primary hypotheses in this study are that childhood cancers were associated with environmental exposure pathways which were identified in earlier reports:

- contamination of potable water from UWTR Parkway well field by the Reich Farm Superfund site;
- contamination of potable water from UWTR Holly Street well field, due to wastewater discharge into the Toms River from the Ciba-Geigy site;
- contamination of potable water affecting private wells near the Reich Farm and Ciba-Geigy sites and other areas in Dover Township from other or unknown sources; and
- air pollution emissions from the Ciba-Geigy facility.

Potential exposure to other environmental factors are also considered in order to address community concerns. The first of these environmental factors is the potential exposure to ambient air releases from the Oyster Creek Nuclear Generating Station, located approximately ten miles south of Dover Township. The next factor is residential proximity to sites in the area which concerned the community: the Ciba-Geigy Superfund site; a section of the Toms River where treated wastewater was discharged (1952 to 1966) from the Ciba-Geigy facility; the Ciba-Geigy pipeline which transported treated wastewater across Dover Township (1966

to 1991) and experienced four locations of documented breaks (1984, 1986, 1988, and 1989) during its usage; the Reich Farm Superfund site; the Dover Township Municipal Landfill; the Ocean County Landfill; and the Toms River Coal Gas site. The last of these factors is the year of construction of the birth residence.

Study Design Overview

The epidemiologic study uses a case-control design to evaluate possible risk factors and the magnitude of their association with childhood cancers in Dover Township. The risk factors evaluated include the environmental exposures comprising the primary hypotheses and other factors which have been evaluated in other studies of childhood cancer. A case-control study design was selected because it is the best epidemiological method for studying rare diseases.

The study has two separate components: the Interview Study and the Birth Records Study. In the Interview Study, residential histories were collected by telephone interview using a structured questionnaire. In the Birth Records Study, residence of the mother at the time of the child's birth was obtained from the birth certificate. The primary data used to address the environmental hypotheses were drawn from residential histories (Interview Study) or from birth certificates (Birth Records Study), combined with modeled water distribution or air pollution exposure estimates. Information on other factors was collected through the questionnaire (Interview Study) or the birth certificate (Birth Records Study) because these potential risk factors have been previously studied in other investigations of childhood cancer or are potential confounders of the environmental factors.

The relative risk (odds ratio) of childhood cancers was computed using conditional logistic regression to evaluate the degree to which exposure factors were associated with disease. An exposure odds ratio is the ratio of the likelihood of exposure among cases relative to the likelihood of exposure among controls. An OR greater than one means that the exposure factor was more common in cases than controls. Conversely, an OR less than one means that the exposure factor was less

common in cases than controls. The 95% confidence interval was calculated to assess statistical association between exposure and disease. The width of the confidence interval is a measure of the certainty of the estimated OR. Because of the small number of subjects in this study, a relatively large odds ratio is needed before it reaches statistical significance; this is especially true for certain small strata analyses.

Odds ratios were computed for two age groups (children diagnosed prior to age 20, and children diagnosed prior to age five). For the Interview Study, ORs were computed for each of four diagnostic cancer groupings: leukemia and nervous system cancers combined; leukemia; all nervous system cancers; and brain and central nervous system cancers. For the Birth Records Study, ORs were computed for each of five cancer groupings: all cancers combined; leukemia; all nervous system cancers; brain and central nervous system cancers; and all other cancers.

The potential causal association of a risk factor with an outcome was evaluated using a combination of criteria, including: strength of the association (magnitude of the OR), statistical significance, consistency of findings of multiple measures for an exposure, apparent dose response effect, and evidence of a completed exposure pathway.

Interview Study

The Interview Study focused solely on the types of cancers that were found to be elevated in Dover Township. A case was defined as a child who was diagnosed between 1979 and 1996 with leukemia or nervous system cancer before 20 years of age while residing in Dover Township. Cases were identified from New Jersey State Cancer Registry records . Four controls were matched to each case by age, sex, and residence in Dover Township at the time the case was diagnosed. Controls were identified from Toms River School District student rosters. A structured questionnaire was developed and administered to the parent or guardian over the telephone by experienced NJDHSS interviewers. Information was collected for the time period comprising one year prior to birth to the month and year of the case's diagnosis.

Consequently, a few parents were required to recall information from as early as 1962.

Interviews were conducted for a total of 40 children who met the case definition: 22 with leukemia and 18 with nervous system cancers (5 of which were sympathetic nervous system cancers and 13 of which were brain and central nervous system cancers). There were no interviews for 39 potentially eligible controls, primarily due to parent refusals or lack of response after repeated contact attempts. Interviews were conducted for a total of 159 controls. The overall study participation rate was 84% (100% of cases and 80% of controls).

Using information from birth certificates, the participating and nonparticipating controls were found to be generally similar for average weight at birth, race, and maternal age at the time of child's birth. However, nonparticipating eligible controls were found to have been born earlier in the study time period, were less likely to have a mother residing in Dover Township at the time of their births, and were less likely to be the mother's first born child than the participating controls.

The excellent response rates and cooperation of study families were strengths of the Interview Study. Limitations of the Interview Study included the study's low statistical power to detect significant results and potential recall bias.

Birth Records Study

In order to address community concerns that children may have moved away from Dover Township prior to being diagnosed with cancer, the Birth Records Study was conducted and evaluated all types of childhood cancer. A case was defined as a child who was diagnosed with any type of cancer before 20 years of age and whose mother was a resident of Dover Township at the time of the child's birth. All births from 1966 through 1996 among residents of Dover Township, identified from New Jersey Vital Statistics records, were compared with the New Jersey State Cancer Registry records, 1979 through 1996, and nine other state cancer registries. Although not all states have cancer registries, these nine states were included

because they have cancer registries and were the destination of 70% of Ocean County out-migrants between 1985 and 1990, according to U.S. Census data. Ten controls, who matched each case by year of birth and sex, were randomly selected from all births to Dover residents. The cases were then each compared to their ten matched controls with respect to variables contained on the birth certificate.

A total of 528 children were enrolled in the Birth Records Study (48 cases and 480 controls). There were a total of 16 children with leukemias, 13 children with nervous system cancers, and 19 children with some other type of cancer. Of the 48 cases, 41 were residents of Dover Township when diagnosed with cancer, five of the cases resided in another Ocean County community, one resided in another New Jersey county, and one resided in another state at the time of their diagnosis. Of the 41 cases who were residents of Dover Township both at birth and diagnosis, 24 were diagnosed with leukemia or nervous system cancer, and thus were also included in the Interview Study.

Since birth certificates were used as the source of the information collected for study children, a strength of the Birth Records Study is that this type of data is free of exposure misclassification due to recall error. Another strength is that case and control selection was likely unbiased. Limitations of the Birth Records Study include: lack of available information on the child's postnatal exposures, limited amount of prenatal information, the birth address may not be the mother's residence throughout the pregnancy, and low statistical power.

Environmental Factors

Household Drinking Water Source Exposure

Three major study hypotheses were evaluated regarding association with childhood cancer incidence: exposure to the United Water Toms River (UWTR) public water distribution system's Parkway well field water; exposure to the UWTR's Holly Street well field water; and exposure to private well water in areas of Dover Township with known groundwater contamination. Since historical contamination of

the Holly Street and Parkway well fields has been documented, human exposure to the contaminated water became one of the critical risk factors to be examined. However, because contamination was not continuously present at either the Parkway or Holly Street well fields throughout the entire study time period, the study also evaluated potential contaminant time windows regarding the possible period of contamination of each well field. Exposure indices developed without the use of contaminant time windows will be referred to as unadjusted while those indices developed with contaminant time windows will be referred to time-specific in later discussions.

For the Holly Street well field, pollution was documented for the mid-1960's, but the duration of contamination was unknown. The source of the Holly Street well field contamination was believed to be Ciba-Geigy wastewater discharged into the Toms River from 1952 to 1966. By the mid-1970s very little water from contaminated wells of the Holly Street well field was being pumped into the water distribution system. Consequently, for the purpose of the study the period of 1962 through 1975 was assumed to comprise the time frame of potential exposure to contaminated Holly Street well field water. However, because of the uncertainty of the length time of contamination of the Holly Street well field, an alternate exposure time frame was calculated assuming contamination of the well field through 1980, the last year of documented use of a previously contaminated well in the well field.

The Parkway well field became contaminated at some point after the illegal disposal of thousands of drums of chemical waste at the Reich Farm site, which occurred in 1971. Although contamination of the Parkway well field was first documented in 1986, it is unknown when the contamination first affected the well field. It has been estimated that groundwater contamination from the Reich Farm site may have taken approximately ten to fifteen years to reach the Parkway well field. Therefore, for the purposes of this study, the period of 1982 through 1996 (the end of the study period) was assumed to comprise the time frame of potential exposure to contaminated Parkway well field water. Other alternate time frames,

assuming a contaminant transit time of as little as six years (1978) to as long as 14 years (1986), were also evaluated.

The chemical composition of the groundwater contamination which resulted from the dumping of chemical wastes at Reich Farm had not been well characterized previous to the current investigation. A variety of chemicals including two carcinogens, trichloroethylene and tetrachloroethylene, and a previously unknown material, styrene-acrylonitrile (SAN) trimer, have been found in the plume. However, since the concentration of the contaminants impacting the Parkway well field over the years is unknown, the risk potential to the community is not well understood. Consequently, the true carcinogenic and non-carcinogenic potential of the contamination mixture in this completed exposure pathway remains unknown.

Exposure to public water from the eight additional UWTR well fields (Anchorage, Berkeley, Brookside, Indian Head, Route 70, Silver Bay, South Toms River, and Windsor) was also evaluated. To evaluate potential exposure to contamination from private well use, 11 areas in Dover Township with a history of groundwater contamination were delineated (for more detail see Volume IV, Appendix D).

Computer-based reconstruction modeling conducted by ATSDR was used to derive monthly estimates of the percent of water delivered to each study residence from each well field in the public water distribution system from 1962 through 1996 (for more detail see Volume IV, Appendix D). From these modeled data, the average percent of public water delivered (called the exposure index) from each of the well fields was calculated for each study subject using residential information. Three exposure categories were formed: low (receiving less than 10% of their water from the specified public well field); medium (receiving 10% to 49.9% of their water from the specified public well field); and high (receiving 50% or more of their water from the specified public well field).

In the Interview Study, information was also collected on the average daily amount of tap water consumed by the mother during pregnancy and by the child

from birth to the date of diagnosis. Additional exposure indices were created using the tap water consumption information combined with the average public water source percentages, called the water source/consumption indices.

Although computer modeling of the public water distribution system was the most objective method available to estimate past exposure to well field water (the vehicle for the actual distribution of environmental contaminants), there are limitations in the exposure assessment. In developing the historic model reconstructions, a number of assumptions were made on how the system operated over time. Altering system operations, such as when wells were pumping, might affect the estimated percentage of water delivered to a particular location from any well field. In order to evaluate the uncertainty and variability in system operations, ATSDR used multiple system assumptions to recalculate water percentage estimates. This sensitivity analysis found that estimates were very similar regardless of which system operations were employed. Consequently, the use of computer modeling for the water exposure assessment was a strength in the Interview and Birth Records Studies.

Another strength of the Interview Study was its ability to evaluate potential exposure during specific critical time periods: the total study time period (one year prior to birth to the date of diagnosis); the prenatal time period; and the postnatal time period. For the Birth Records Study, only the residence at birth was available to assess exposure during the prenatal time period. Additionally, in the Birth Records Study the source of water used in the home (private well or public water) was unknown and was assumed to be public water if the water distribution system was on the street of the residence during the year of the child's birth.

Results for Public Water Well Fields: Exposure to unadjusted Holly Street well field water, time-specific Holly Street well field water, and alternate time-specific Holly Street well field water did not appear to be associated with any childhood cancer groupings in either the Birth Records or Interview Studies. However, it should be noted that the exposure pathway was interrupted early in the study period, so only

a limited number of study subjects were potentially exposed.

Exposure to unadjusted or time-specific Parkway well field water did not appear to be associated with any of the childhood cancer groupings when males and females were analyzed together. However, when exposure to time-specific Parkway well field water was analyzed separately by sex, a noticeable pattern of elevated odds ratios was found in the Interview Study. For the prenatal time-specific Parkway well field water high exposure category, a five-fold increased risk was found for females diagnosed with leukemia (OR=5.0; 95% CI=0.8, 31). Also for females diagnosed with leukemia, the prenatal time-specific Parkway well field water source/consumption high exposure category was significantly elevated (OR=6.0; 95% CI=1.1, 32). While the addition of tap water consumption to the unadjusted Parkway well field water source variable only modestly increased the odds ratio (see Figure 1), the time adjustment noticeably increased both the unadjusted water source and the unadjusted water source/consumption variables.

Because of the uncertainty when contaminated groundwater reached the Parkway well field, odds ratios were recalculated using alternate temporal adjustments regarding the year the well field became contaminated. The original time-specific Parkway well field variable assumed an exposure period of 1982 through 1996. Eight annual incremental adjustments were made to calculate alternate prenatal time-specific Parkway well field variables assuming a contaminant transit time of as little as six years to as long as 14 years. The eight new contaminant time windows include 1978-1996, 1979-1996, 1980-1996, 1981-1996, 1983-1996, 1984-1996, 1985-1996, and 1986-1996. During the prenatal period, the odds ratios remained elevated for all of the high exposure categories of the alternate time-specific Parkway well field water variable for females diagnosed with leukemia, with the 1984-1996 exposure period displaying the highest odds ratio (OR=15; 95% CI=0.8, 274). Of note, female leukemia cases in the high prenatal Parkway well field exposure category were all born after 1983.

Although no associations were detected in analyses of the overall study

population, a statistically significant association and consistency in multiple measures of association were seen between prenatal exposure to time-specific Parkway well field water (1982-1996) and leukemia in female children. These findings are consistent with one of the study's a priori hypothesis that exposure to Parkway well field water during this interval was a risk factor for childhood leukemia.

The high exposure category for time-specific Parkway well field during the postnatal period did not display a similar pattern for female children with leukemia. None of the unadjusted or time-specific Parkway well field indices for leukemia in males or the unadjusted or time-specific Parkway well field indices for brain and central nervous system cancers displayed any pattern or consistency. The results from the Birth Records Study analysis did not display any pattern or consistency of association with any childhood cancer groups evaluated.

Although there were no known exposure pathways associated with the eight other public water supply well fields (Anchorage, Berkeley, Brookside, Indian Head, Route 70, Silver Bay, South Toms River, and Windsor), analyses were conducted. Odds ratios for these other well fields fluctuated above and below 1.0 in both the Interview and Birth Records Study with no consistent pattern detected. Many of these well fields supplied only small amounts of water to a limited number of study residences.

Results for Private Well Water: For both the Interview and Birth Records Study, few study children ever lived in a household with a private well in any of the 11 groundwater regions that had a history of groundwater contamination. In general, no elevation of risk or consistent pattern was found for childhood cancer and exposure to private wells in a potentially contaminated groundwater region. However, in the Interview Study the odds ratios for ever using a private well in a residence in any of these 11 groundwater regions during the total time and postnatal time were both over 5.0 for leukemia (males and females combined). The elevated odds ratios were based on two case children (1 male and 1 female) both with leukemia, whose residence used a private well, but were in two separate

groundwater regions. The prenatal leukemia odds ratio could not be calculated since there were two cases but no controls with private well usage in any of these groundwater regions during that time period.

Exposure to Air Pollution from Point Sources

Computer modeling was used to derive monthly estimates of potential exposure at each study residence to ambient air emissions from two facilities in the Dover Township area: Ciba-Geigy and Oyster Creek Nuclear Generating Station, from 1962 through 1996 (see Volume IV, Appendix F). Data from this modeled effort provided the average amount of ambient air emissons from each facility and was used to calculate an exposure index for each study subject using residential information.

As with the water distribution system modeling, this was the most objective method available to estimate the past exposure. However, the quality of input data for the air models was not considered to be as high quality as in the water modeling. This was particularly true for the Ciba-Geigy models where actual emission data was unavailable and weather data used was from a station fifty miles away. In an effort to address the missing emission data, annual production information for the Ciba-Geigy facility was used to modify the monthly exposure estimates used in the exposure assessment. Additionally, EOHSI conducted sensitivity analyses using weather data available for a portion of the study period from a closer weather station and also used a different model to calculate estimates for comparison. In general, both the use of a different model and the use of closer weather data produced higher exposure estimates than the data used for the exposure assessments. Exposure estimates for Oyster Creek were considered better since they were generated using actual emission data and on-site weather information.

Manufacturing operations at the Ciba-Geigy facility began in 1952 and ceased in 1996. Over the years, the facility produced anthraquinone-based dyes, azo dyes, epoxy resins, and other specialty chemicals. Ciba-Geigy was the only industrial

facility in the Dover Township area which met the New Jersey Department of Environmental Protection's definition of a major emitter of hazardous air pollutants, including carcinogenic materials. Very limited historic emissions data for the facility were available to adequately characterize potential exposure to the community. Modeled Ciba-Geigy ambient air emission estimates were closely correlated with modeled ambient particulate levels and are likely a surrogate of exposure to both gaseous and particulate air pollution arising from the site.

Exposure indices were created for Interview Study subjects for three time periods: the total study time period (from one year prior to birth until the date of diagnosis); the prenatal time period; and the postnatal time period. For the Birth Records Study, only exposures at the birth residence were evaluated for the prenatal period, since no other exposure data were available. Three exposure categories were calculated for the air pollution indices: low, medium, and high. These categories were determined using the 50th and 75th exposure percentile values within the control population.

Results for Air Pollution Sources: Exposure to Ciba-Geigy ambient air emissions did not appear to be associated with childhood cancers when both sexes were evaluated together. However, when evaluated separately, females with leukemia displayed a noticeable pattern. In the Interview Study, elevated odds ratios were found for the high and medium prenatal exposure categories for Ciba-Geigy ambient air emissions in females with leukemia diagnosed prior to age five (high exposure category OR=19, 95% CI=0.9, 397; medium exposure category OR=5.2, 95% CI=0.5, 57). Five of the seven female leukemia cases under age five were in the medium or high Ciba-Geigy exposure categories while only nine of 27 controls were in those categories. When the medium and high Ciba-Geigy prenatal exposure categories were collapsed into a single exposure category, the new odds ratio for leukemia in females diagnosed prior to age five was elevated (OR=7.5; 95% CI=0.8, 71) relative to the low exposed group.

For the Birth Records Study, only the prenatal period was evaluated and it was

assumed that the residence at birth was also the residence throughout the pregnancy. As in the Interview Study, elevated odds ratios were found in the Birth Records Study for the high and medium exposure categories of Ciba-Geigy ambient air emissions for prenatal exposure in females diagnosed with leukemia prior to age five (high exposure category OR=7.8, 95% CI=0.8, 77; medium exposure category OR=2.0, 95% CI=0.1, 35).

Although no associations were detected in analyses of the overall study population, a consistent elevation in the odds ratios and an apparent dose response effect was seen in both the Interview and Birth Records Studies (see Figure 2) between prenatal exposure to Ciba-Geigy ambient air and leukemia in female children diagnosed prior to age five. These findings are consistent with one of the study's a priori hypothesis that exposure to Ciba-Geigy ambient air emissions was a risk factor for childhood leukemia.

In the Interview Study, the postnatal high exposure category was also elevated for Ciba-Geigy ambient air emissions (OR=5.5, 95% CI=0.3, 122) for females diagnosed with leukemia prior to age five.

In general, all of the estimated Oyster Creek ambient exposures were far below the limit of detection of 70 fCi/m^3 for $iodine^{131}$. A lifetime cancer risk from the exposure levels estimated by the computer modeling is extremely low, on the order of about one in a billion. Exposure to Oyster Creek ambient air emissions did not appear to be associated with any childhood cancer groups evaluated in either the Interview or Birth Records Studies.

Other Environmental Factors

Residential distance within one-half mile of a site of concern was also evaluated as a risk factor. Because relatively few study children ever lived within one-half mile of a site of concern, an index of ever/never having lived near a site was used, rather than the percent of time a child lived near the site. For the Interview Study, exposure indices for ever having lived within one-half mile of a site of concern

were created for three time periods: the total study time period (from one year prior to birth until the date of diagnosis); the prenatal time period; and the postnatal time period. For the Birth Records Study, only the birth residence was evaluated for the prenatal time period, and it was assumed that the mother's residence at the time of the child's birth was the mother's residence throughout the pregnancy period.

Residential proximity to a site was not specific to an exposure pathway, as were the air and water distribution modeling or groundwater plume shapes. Residential proximity was evaluated because it might capture other routes of exposure that could not be accounted for in the more sophisticated assessments, such as potential exposure through contact with the site. In general, the indices developed using proximity to sites of concern should be considered to be a less accurate estimate of potential exposure than indices derived using the computer model estimates.

In a separate investigation, EOHSI evaluated attic house-dust in Dover and non-Dover households for the presence of select chemical and radiological contaminants. While there was little difference detected between the Dover and non-Dover homes, it was noted that cesium 137 levels were higher in the attics of older (pre-1970) houses and concluded that it was primarily the result of above-ground nuclear weapons testing and global fallout that occurred in the 1950s and 1960s.

Information on the year of construction of the house where the parents resided at the time of the child's birth was collected from Dover Township municipal records for birth residences in the Birth Records Study. In the Interview Study, information on the year of construction of the birth address was not collected during the interview. In addition, birth residences of children in the Interview Study were in many municipal locations and information on year of construction was not generally available for all birth addresses. Consequently, evaluation of year of construction was only conducted for the Birth Records Study. Birth residences were categorized into older homes (built prior to 1970) and newer homes (build from 1970 onward).

Results for Residential Proximity to Sites of Concern: In the Interview Study, the only site of concern displaying any pattern or consistency in elevated odds ratios was ever having lived within one-half mile of the Ciba-Geigy pipeline (during the total study time, prenatal, and postnatal periods) among females diagnosed with leukemia (ORs ranging between 5.1 and 17). Because residential distance to the entire pipeline was a fairly crude estimate of exposure, a more refined index was developed in an attempt to better define the potential exposure pathway of the pipeline. The new index evaluated residential proximity to four locations with known breaks in the pipeline (after the breaks occurred). When residential proximity to a break in one of these four pipeline locations was taken into consideration, few of the total study population (5 cases and 14 controls) were ever exposed, and the odds ratios diminished.

As noted above, for the Birth Records Study, only odds ratios for the prenatal period were evaluated. There was no pattern or consistency in the odds ratios for proximity to the pipeline or any other site of concern in the Birth Records Study. The index for proximity to the Ciba-Geigy pipeline was statistically significantly correlated with the time-specific Parkway index in the Interview Study (r=0.30), but no statistically significant correlation was found in the Birth Records Study. It is important to note that no completed exposure pathways associated with the Ciba-Geigy pipeline were identified in the Ciba-Geigy Public Health Assessment.

Results for Birth Residence Year of Construction: Of the 528 birth residences, information on the year of construction was available from municipal records for 438 homes (83%). For all study children with a birth residence of known year of construction, cases and controls had nearly equal percentage of older homes (64% vs. 62%). While older residences were not statistically significantly associated with any of the case groupings, the odds ratio for brain and central nervous system cancers was elevated fourfold (OR=4.3; CI=0.5, 40).

Other Factors

The etiologic factors for childhood cancer are not well understood. Numerous studies have been conducted to evaluate a variety of factors which might be associated with an increased risk of childhood cancer. With the exception of a few factors that have been consistently identified in the literature (certain genetic diseases and prenatal exposures to ionizing radiation) there is an absence of consistency for most other potential risk factors examined to date. For a more detailed discussion on the etiology of childhood cancers, see Volume IV, Appendix B. In addition to the distinct environmental factors evaluated in this study, information on a wide variety of other factors was collected. These factors were included because they have been suggested in other studies to be associated with childhood cancer, or may be potential confounders to the environmental factors of interest.

In general, most of the other factors displayed no differences between the cases and controls. Study findings related to the other factors were found to be generally consistent with the published literature, with the exception of consumption of cured meat which displayed a protective effect, in contradiction to the published reports that suggest cured meats are a risk factor for some childhood cancers.

Conclusions

As the final part of the investigation of the incidence of childhood cancer in Dover Township, Ocean County, the New Jersey Department of Health and Senior Services (NJDHSS) and the federal Agency for Toxic Substances and Disease Registry (ATSDR) conducted an epidemiologic case-control study to evaluate distinctive environmental exposure pathways identified in this community during earlier phases of the Public Health Response Plan. Association of selected childhood cancer with these environmental pathways represent the study's primary hypotheses.

Highlights of the study findings are presented in Table 1. The results in this Final Report should be interpreted carefully and in conjunction with existing biological and epidemiologic knowledge. Due to the relatively small number of study subjects, the analyses are sensitive to random fluctuations in numbers, which can result in

substantial imprecision in the odds ratios (reflected by wide confidence intervals). Based on a combination of evaluation criteria for determination of risk factor and cancer causal associations, NJDHSS and ATSDR have concluded the following:

* Several environmental factors of primary interest were found to be associated with leukemia in female children, specifically for the prenatal exposure time period. These associations were not found in male children.

* No environmental factor of primary interest appeared to be associated with brain and central nervous system cancer in either males or females.

* No consistent patterns of association were seen between the environmental factors of primary interest and any of the cancer groupings during the postnatal exposure period.

* Although no associations were detected in analyses of the overall study population, a statistically significant association and consistency in multiple measures of association were seen between prenatal exposure to time-specific Parkway well field water (1982-1996) and leukemia in female children of all ages. This finding seems to support the hypothesis that prenatal exposure to Parkway well field water during this interval was a risk factor for childhood leukemia in females. However, it is important to note that there is considerable uncertainty in the findings.

* Although no associations were detected in analyses of the overall study population, a consistent elevation in the odds ratios and an apparent dose response effect was seen in both the Interview and Birth Records Studies between prenatal exposure to Ciba-Geigy ambient air and leukemia in female children diagnosed prior to age five. This finding seems to support the hypothesis that exposure to Ciba-Geigy air emissions was a risk factor for childhood leukemia in females. As noted above, there is considerable uncertainty in the findings.

* No associations were seen between exposure to Holly Street well field water prior to 1976 and any of the cancer groupings evaluated. However, because few children had any study time before 1976, the ability to examine this factor was limited in this study.

* The use of a private well for drinking water within any region that had a history of groundwater contamination was rare in this study. Odds ratios for leukemia were elevated in the Interview Study for ever living in a residence with a private well in any of these groundwater regions during the postnatal

time period, but could not be calculated for the prenatal period.

* An association was observed during the prenatal and postnatal time periods for residential distance from the Ciba-Geigy pipeline and leukemia in female children, but the association diminished when documented Ciba-Geigy pipeline breaks were taken into consideration. No completed exposure pathways associated with the Ciba-Geigy pipeline were identified in the Ciba-Geigy Public Health Assessment.

* No consistent patterns of association were seen between the other environmental factors and any of the cancer groupings evaluated.

* Study findings related to the other factors evaluated were found to be generally consistent with the published literature, with the exception of the consumption of cured meat variables.

* The ability to adjust for confounding in this study was limited due to the limited number of study subjects.

Recommendations

5. The NJDHSS should update the *Childhood Cancer Incidence Health Consultation* when an additional five years of cancer incidence data (1996-2000) are available from the New Jersey State Cancer Registry in order to determine if there are any changes in childhood cancer incidence rates or time trends in Dover Township.

6. Efforts should be continued to cease or reduce exposure to hazardous substances, including:

   - The effort to ensure that the Reich Farm groundwater pollution does not cause contamination of additional Parkway well field wells should be continued in order to guarantee that this exposure pathway is not completed. Periodic groundwater sampling of the Reich Farm plume should continue in order to ensure that the plume is accurately delineated and does not affect currently unaffected public supply wells. In addition, monitoring of the effectiveness of treatment systems now in place is necessary to ensure that contaminants are not reintroduced into the community water distribution system.

   - All private well restriction zones in Dover Township should be maintained in order to ensure that this potential exposure pathway is not completed.

   - Continued efforts should be made by the United States Environmental Protection Agency and Ciba Specialty Chemicals to contain and remove contaminants in the affected aquifer associated with the Ciba-Geigy site. The restrictions on the use and construction of private wells in areas known to be affected by the Ciba-Geigy site should be maintained. The remediation of the Ciba-Geigy property should continue in order to reduce the threat of further contamination of groundwater and prevent future exposures to hazardous chemicals.

3. Because of the complexity of issues in Dover Township, it would be beneficial to continue educational efforts on cancer, such as providing study-specific information and environmental health information to teachers and children in the schools, to health care providers, and to the community at large.

Table 1. Case-control Study of Childhood Cancers in Dover Township: Highlights of Interview and Birth Records Study Findings for Environmental Exposure Factors

Exposure Factor	Highlight
Parkway Well Water, Time-specific	**Interview Study:** - No association seen in the overall leukemia or brain and central nervous system cancer groupings. - For females, age 0-19, elevated odds ratio for the high exposure category during the prenatal period and leukemia (OR=5.0). - When tap water consumption was incorporated, the prenatal exposure odds ratio for the high exposure category was statistically elevated for females with leukemia (OR=6.0). - No association seen for females during the postnatal exposure period. - No association seen for prenatal or postnatal exposures in males. **Birth Records Study:** - No association seen in the overall leukemia or brain and central nervous system cancer groupings or any of the subgroups evaluated.
Holly Street Well Field Water, Time-specific	- No association seen in the overall leukemia or brain and central nervous system cancer groupings or any of the subgroups evaluated in either the Interview or Birth Records Studies.

Exposure Factor	Highlight
Other Public Water Supply Well Fields	- No association seen in the overall leukemia or brain and central nervous system cancer groupings or any of the subgroups evaluated in either the Interview or Birth Records Studies.
Private Wells in Groundwater Regions with History of Contamination	**Interview Study:** - Few study children ever lived in a residence with a private well in any of the groundwater regions. - No association seen in the overall leukemia or brain and central nervous system cancer groupings. - Postnatal exposure for males and females combined was elevated for leukemia (OR=5.4). - Prenatal exposure odds ratios could not be calculated for leukemia; 2 cases and no controls were exposed. **Birth Records Study:** - Only two study children had a birth residence in any of the groundwater regions. - No association seen in the overall leukemia or brain and central nervous system cancer groupings.

Exposure Factor	Highlight
Ciba-Geigy Ambient Air Pollution	**Interview Study:** - No association seen in the overall leukemia or brain and central nervous system cancer groupings. - For females with leukemia, age 0-4, prenatal exposure displayed elevated odds ratios for the medium exposure category (OR=5.2) and the high exposure category (OR=19). - The high exposure category odds ratio for females, age 0-4, during the postnatal period was elevated for leukemia (OR=5.5). - No association seen for the prenatal or postnatal exposures in males. **Birth Records Study:** - No association seen in the overall leukemia or brain and central nervous system cancer groupings. - For females with leukemia, age 0-4, the prenatal odds ratio was elevated for the high exposure category (OR=7.8).
Oyster Creek Ambient Air Pollution	- No association seen in the overall leukemia or brain and central nervous system cancer groupings in either the Interview or Birth Records Studies. - All of the exposure estimates for Oyster Creek were extremely low, with a lifetime cancer risk on the order of about one in a billion.

Exposure Factor	Highlight
Residential Proximity to the Ciba-Geigy Pipeline	**Interview Study:** - An association seen for proximity to Ciba-Geigy pipeline and leukemia, both sexes combined and females separately, during prenatal and postnatal periods (odds ratios ranging from 2.3 to 14). - Associations with leukemia diminished when proximity to documented Ciba-Geigy pipeline breaks was evaluated separately. - No completed exposure pathways associated with the Ciba-Geigy pipeline were identified during the Ciba-Geigy Public Health Assessment. **Birth Records Study:** - No association seen in the overall leukemia or brain and central nervous system cancer groupings.
Residential Proximity to Other Sites of Concern	- No association seen in the overall leukemia or brain and central nervous system cancer groupings or any of the subgroups evaluated in either the Interview or Birth Records Studies.
Birth Residence Year of Construction Before 1970	**Birth Records Study:** - No association seen in the overall leukemia group. - Odds ratio elevated for brain and central nervous system cancer (OR=4.3), males and females combined.

Figure 1: Interview Study Summary of Parkway Well Field Prenatal Water Indices for Females

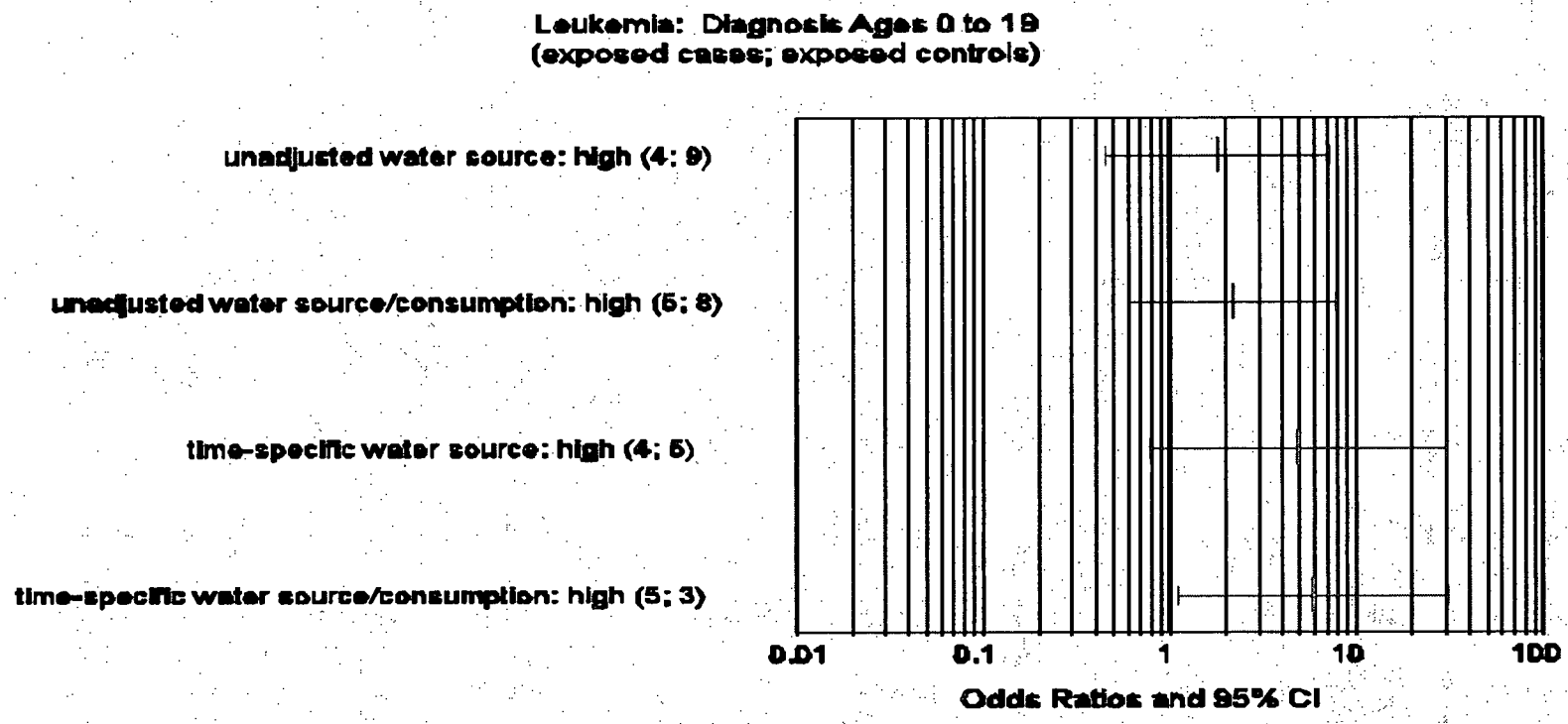
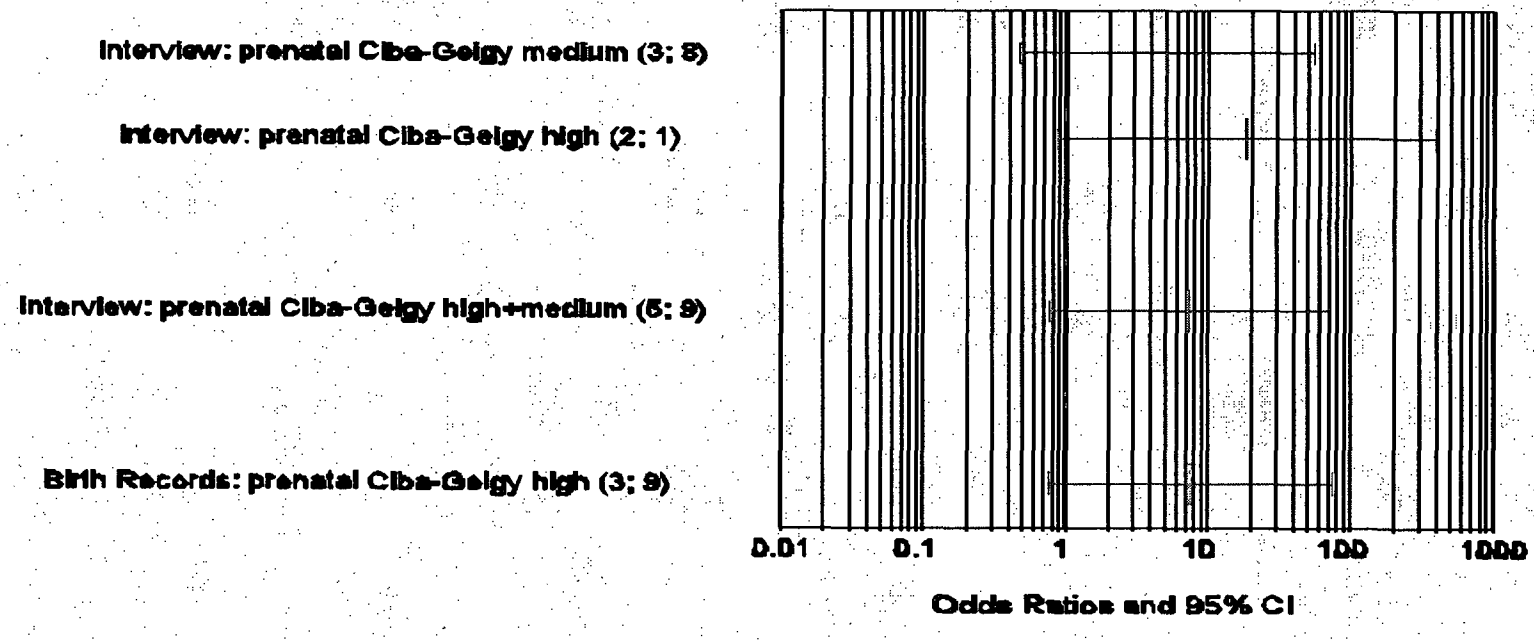


Figure 2: Interview and Birth Record Study Summary of Prenatal Ciba-Geigy Ambient Air Indices for Females

Leukemia: Diagnosis Ages 0 to 4
(exposed cases; exposed controls)