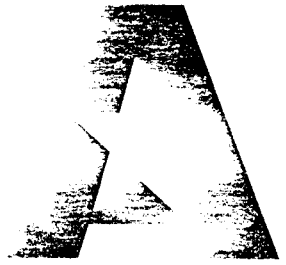

A CRITICAL REVIEW OF CANCER IN TEXAS

With Emphasis on Environmental and Occupational Exposures

The University of Texas-Houston
School of Public Health

Southwest Center for Occupational
and Environmental Health

JULY 1994

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This study was funded by a research agreement between The University of Texas Houston Health Science Center School of Public Health, and the Texas Institute for Advancement of Chemical Technology, Inc. (TIACT). Single copies of the report may be obtained at no charge from TIACT, Mail Stop 3125, Texas A & M University, College Station, Texas 77843-3125; telephone (409)845-3372; FAX (409)862-4202. The authors may be reached at The University of Texas-Houston School of Public Health, P.O. Box 20186, Houston, Texas 77225; telephone (713)792-7457.

Nature of Research Agreement and Acknowledgements

This project was supported by a research agreement between The University of Texas Houston Health Science Center School of Public Health, and the Texas Institute for Advancement of Chemical Technology, Inc. (TIACT), a non-profit organization composed of industry and other private and public sector members. The contract encouraged and guaranteed the rights for independent publication by the investigators in the scientific literature. A study Steering Committee (see following list) composed of academic, government, and industry professionals advised TIACT as to scientific issues and study progress, and served as an optional resource to the study investigators in terms of identifying studies for review and accessing cancer mortality data, but were otherwise uninvolved in study proceedings. TIACT also engaged four outside epidemiologists; two early in the study to review study plans and the draft final report (Philip Cole, M.D., M.P.H.--Professor of Epidemiology, University of Alabama School of Public Health and Michael Greenberg, Ph.D--Professor, The State University of New Jersey, Rutgers), and two at the end of the study to serve as peer reviewers of the draft final report (Harvey Checkoway, Ph.D., Professor of Environmental Health, University of Washington; Donald Austin, M.D., M.P.H., Senior Medical Advisor, Chronic Disease Program, Oregon Health Division). In addition, Emily Untermeyer, M.P.H., Executive Director, Texas Cancer Council; and Jane Teta, Dr.P.H., Director of Epidemiology, Union Carbide, also reviewed and commented on the draft version of this final report. The Steering Committee and outside reviewers made many constructive comments, many of which were addressed and incorporated into the final report. However, the comments were advisory in nature, and the authors take final responsibility for the content of this report.

The authors would also like to acknowledge the devoted contributions of the study staff to this project: Candiance Duplessis, B.A., for word processing and general study support activities, Deanna Fletcher, P.T., M.P.H., for computerized database searching, Young Kim, M.S., for cancer mortality graphing, and Erin Fletcher for article retrieval and database entry. Particular appreciation is also noted for the generous assistance with the cancer mortality data and analyses by the Cancer Registry Division of the Texas Department of Health, for database design by Charles Cooper, M.S., for cover design by Henry Fung and for printing advice and assistance by Earl Colvin at The University of Texas-Houston Printing Services, and for mapping graphics by Sharon Wells.

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EXECUTIVE SUMMARY

Background and Study Questions

In response to concerns regarding the possible contribution of environmental and occupational exposures to the burden of cancer in Texas, the Texas Institute for Advancement of Chemical Technology, a non-profit organization composed of industry and other private and public sector members, solicited proposals to review critically what is known about cancer in Texas, the second leading cause of death. The University of Texas-Houston School of Public Health was selected to conduct this project. Although no new data were collected, this report constitutes the first attempt to assemble systematically and evaluate critically existing epidemiologic studies pertaining to cancer in Texas. The emphasis of the report on cancer mortality, rather than incidence, reflects the available data from the Texas Department of Health and specific studies. This review describes the magnitude, recent time trends, and geographic variation of cancer mortality in Texas as a framework in which to review the scientific literature about what is known regarding factors contributing to the occurrence of cancer in Texas. A further objective of this review is to identify important gaps in the evidence presently available and identify areas of study to improve cancer control and prevention in Texas.

Mortality Analyses

Available cancer mortality data from the Cancer Registry Division, Texas Department of Health, and published U.S. cancer mortality data were examined to describe the magnitude of cancer mortality and its variation over time and across geographic areas. California cancer mortality data (1988-1990) were used for Hispanic comparisons.

(1) *Cancer Mortality in Texas (1986-1990)*

For 17 selected cancers comprising nearly 80% of all cancer deaths in Texas, average annual age-adjusted mortality rates for Texas were compared to the U.S. for 1986-1990. In general, for most cancers, the rates in Texas were less than or nearly equal to the U.S. rates for non-Hispanic whites and blacks, and to California rates for Hispanics. The most notable statistically significant deficits were for colon and rectum cancer among white males and females, breast cancer among white females, and prostate cancer among black males. The most notable significant excesses were for liver cancer in all race/sex groups except black females and lung cancer in white males, white females, and Hispanic males. Further, total cancer mortality rates were higher for Texas Hispanic males and Hispanic females when compared to California rates.

(2) *Time Trends in Cancer Mortality Rates in Texas (1980-1990)*

Age-adjusted total cancer mortality rates over the years 1980-1990 were found to be significantly increasing for white males and females, Hispanic males, and black males in Texas, similar to the U.S. mortality experience. Most of this increase was accounted for by lung cancer.

For most other cancer types, the rates over the 11 year period were stable. The exceptions, in addition to lung cancer, included statistically significant increases in liver cancer among white and Hispanic males, colon cancer among black and Hispanic males, non-Hodgkin's lymphoma among Hispanic females, and prostate cancer among black males. In all cases, the increases for whites and blacks in Texas were paralleled by increases in the U.S.

When time trends were examined within 24 geographic areas of Texas (1976-1989), the results were most notable for the lack of statistically significant increases or decreases. Statistically significant increasing trends in cancer mortality in several geographic areas were dominated by lung cancer and decreasing trends by stomach and cervical cancer.

(3) *Geographic Variation in Cancer Mortality in Texas (1980-1991)*

Deaths due to cancer of 17 selected sites were examined in 24 geographic areas of Texas for 1980-1991 for six sex/race/ethnic groups and compared to the entire state. In relation to Texas as a whole, eight areas (one area in far west Texas, four areas in northeast Texas, one area in northwest Texas, the southern tip of Texas, and one area in central Texas) experienced significantly lower mortality for multiple cancer sites. Six areas experienced excesses of various cancers more frequently when compared to the entire state of Texas. These areas included far west Texas, one area in south central Texas, and four areas along the Texas Gulf Coast region. However, the excesses and deficits were non-specific in terms of cancer type and sex/race/ethnic group.

Search for Studies and Description of Studies Eligible for Review

To address the major study question regarding what is known about various factors contributing to cancer in Texas, the authors conducted a computerized literature search of 12 major bibliographic databases relevant to epidemiologic studies of cancer in Texas and solicited unpublished reports from major chemical/petrochemical companies, environmental groups, and labor unions.

In order to have been eligible for review, each study must: (1) be an epidemiologic study pertaining to cancer and its risk factors in a Texas population, (2) have completed data collection prior to the initiation of the request for proposal, (3) be in the time frame of the available computerized databases (1964-1993), (4) be publicly accessible, although not necessarily published, (5) have identified authors and affiliations, and (6) be in the form of a written report (not raw data). These sources and eligibility specifications resulted in the collection and review of 136 studies reported from 1964-1993.

Approximately 75% of these 136 studies pertained to cancer and occupational (workplace) exposures compared with less than 5% to lifestyle exposures (e.g., diet, exercise, alcohol). Most of the studies were designed as either historical cohort (n=51) or case-control (n=52) studies. Half of the studies were conducted by authors based at academic institutions, one-third by industry, and the remaining 16% by government agencies. Three-fourths of the reports were

published in peer-reviewed journals. Nearly 60% of the eligible studies were reported in the most recent 10 year period (1984-1993).

Critical Review

The aggregation of cohort studies conducted in 11 refinery and chemical manufacturing plants focused primarily on white male workers. Due to the long latency period for most cancers, the examination of these cohorts would reflect health effects from earlier, and likely heavier exposures. Data from these studies were combined, and summary standardized mortality ratios (SMRs) were calculated by cancer type to compare the observed number of deaths among these workers to that expected in the general population. Overall, among refinery and chemical manufacturing workers, there was a significant deficit in total cancer mortality (SMR=91, 95% CI=86-96) compared to the general U.S. population. The deficits were most apparent for cancers of the buccal cavity/pharynx, digestive cancers, respiratory cancers, and bladder cancer. It is noteworthy that cancers of the lung and liver (which were found to be higher in Texas compared to the U.S.) were significantly lower in petrochemical workers than the general population. There were no statistically elevated risks overall, yet a 10% or greater excess was noted for several cancers, although statistical stability varied. Only the SMRs for central nervous system/brain cancers (SMR=113, 95% CI=96-133) and leukemias (SMR=111, 95% CI=96-128) approached statistical significance.

From cohort studies of more specific populations or case-control studies, various excesses and deficits were detected. However, the attribution of an excess cancer to an occupational cause in these studies was weakened by inconsistency in latency and duration analyses, and non-specificity of the implicated exposures. Further, many other of the reviewed studies which were limited to more specific exposure subgroups and small sample sizes were unable to examine adequately cancer-specific risks.

Based on the qualitative review of other studies, non-occupational risk factors included the protective effect of Vitamin A (carotene) for lung and laryngeal cancer, the increased risk for laryngeal cancer from cigarette smoking and alcohol use, and the major effect of smoking on lung cancer risk for men and women. The evidence about environmental causes (air pollution and drinking water) of cancer in Texas was very limited because of the paucity of studies and the difficulty in defining individual exposure with the methods applied to date.

The small representation of refinery and chemical workers in the Texas work force (<3%) and the small excesses of a few types of cancer, indicate that the cancer excesses among these workers would not impact substantially cancer rates in Texas. Further, specific cancer excesses noted in the entire state were found to be significantly low among the petrochemical workers. However, this applies to Texas as a whole and to total occupational cohorts without regard to duration or intensity of exposure. Therefore, these observations do not preclude a greater impact on cancer mortality in a smaller subset of more highly exposed workers.

Limitations of Available Data

The epidemiologic data included in this review contributed to the identification of higher or lower population rates in cancer mortality and their variation over time and within geographic areas in Texas, and to the identification of factors involved in the causation of cancer in industrial workers and other Texas populations. These critical contributions are ones only epidemiologic studies can make; however, it is also acknowledged that very low level health risks are unlikely to be detected satisfactorily by current epidemiologic methods, especially for risks related to rare cancer types. Similarly, an excess risk of cancer may not be detectable in very small geographic areas. Despite the availability of substantial information on cancer in Texas, several areas were identified in which available data were limited. These areas included:

- ***lack of statewide cancer incidence data***

  Trends in the frequency of cancer occurrence and the identification of various causes of cancer cannot be evaluated properly in light of the incomplete nature of cancer incidence reporting in Texas.

- ***population groups with little or no data***

  Due to small numbers or lack of studies, little or no data were available on black, Hispanic, and female workers; or on migrant and seasonal farmworkers.

- ***limited evidence about environmental causes of cancer***

  The environmental studies of drinking water or ambient air exposures and cancer, conducted to date, have all used the ecologic study design, a design subject to substantial potential bias.

- ***limited exposure information***

  For most studies, it was not possible to identify the exposures corresponding to health outcomes with a precision greater than the general type of plant, or perhaps at times specific process plants, to be linked with health outcomes.

- ***lack of explanation for cancer excesses noted in Texas compared to the U.S.***

  While the cancer mortality experience is generally favorable in Texas compared to the U.S., the possible reasons for the excess in liver and lung cancer remain unresolved.

Conclusions

Based on available studies on cancer in Texas, the overall contribution from the petrochemical industry to cancer mortality in Texas appears to be slight; however, continued study of more highly exposed subgroups, and continuation and initiation of cohort studies are appropriate. The available published occupational data do not usually permit evaluation of cancer risk of workers other than white males, and studies of other groups and in other industries are needed. Further, a confident statement regarding an environmental contribution to cancer in Texas cannot be made with the evidence currently available.

The public health efforts needed to improve cancer control and prevention in Texas should not be held in abeyance while further information is obtained. These include smoking prevention and cessation programs, cancer screening, and reduction in controllable environmental and occupational exposures. Yet, on the basis of the mortality analyses, critical review of the literature, data limitations noted above, and the emphasis of this report on environmental and occupational risk factors for cancer, the following recommendations are made for future research:

RECOMMENDATIONS FOR FUTURE RESEARCH

(1) ***Expand and enhance cancer incidence reporting in Texas by the Cancer Registry Division, Texas Department of Health, with the goal of statewide coverage and complete and timely reporting.*** While mortality data continue to be useful for detecting cancer excesses and monitoring time trends for many cancers, cancer control efforts in Texas are hampered by incomplete cancer incidence data. For cancers with long survival, and for cancers with effective treatments, cancer mortality will not continue to serve as an adequate substitute for incidence.

(2) ***Expand and refine the cancer mortality analyses presented in this report.*** The mortality analyses regarding the magnitude of rates, time trends, and geographic variation were based on available published and unpublished data. Additional specific analyses are recommended in the report.

(3) ***Code death certificate information on usual occupation and industry and enter into the computerized mortality files.*** Currently, these data are recorded on Texas death certificates, but are not coded for computerized access. These data have been used elsewhere as a screening tool to examine possible high risk and low risk occupations and industries.

(4) ***Update periodically industry-based cohort mortality studies to monitor trends in cancer risk and to increase the sample size of the studies. Initiate cohort incidence studies.*** Only four of the 43 cohort studies included in this review have followed the cohort through the 1980s. Complete statewide cancer incidence reporting would allow the matching of workers in these cohorts to cancer registry data to implement cohort incidence studies.

RESEARCH RECOMMENDATIONS CONTINUED

(5) ***Continue and expand occupational epidemiologic studies in previously understudied working populations.*** Currently, constrained by small numbers, cancer risks have not been examined adequately in black, Hispanic, or female petrochemical workers. With opportunity for exposure, and substantial numbers of workers, studies of cancer should also be initiated in farmworkers in Texas.

(6) ***Continue research regarding occupational factors contributing to brain cancer and leukemia.*** Existing data should be exploited by completing and publishing analyses on two population-based case-control studies on brain cancer and leukemia conducted in the Gulf Coast area of Texas.

(7) ***Investigate factors influencing the excess of liver and lung cancer mortality and the deficit of colorectal, prostate, and breast cancer mortality.*** The misclassification of liver cancer as ascertained by death certificates is substantial; therefore, careful investigations of populations in Texas need to incorporate incidence data with histologic confirmation. Since various sex/race/ethnic groups along several areas of the Gulf Coast experienced greater than expected numbers of lung cancer deaths, epidemiologic investigations of environmental exposures along the Gulf Coast area are recommended. The noted deficits occurred for cancers which are detectable by screening. Screening practices for these cancers in Texas should be examined.

(8) ***Initiate analytic studies of environmental exposures and cancer in Texas.*** These studies should incorporate refined measures of exposure, sources of pollution, and individual control for potential confounding factors, such as smoking.

(9) ***Incorporate industrial hygiene measurements and biologic exposure index sampling, when feasible, into future epidemiologic research.*** An increase in precision of the exposure assessment would reduce problems in misclassification inherent in the current use of surrogates of exposure such as job title.

(10) ***Describe smoking profiles for Texas.*** These data would be useful in interpreting future patterns of smoking-related cancers. Currently, data from the Centers for Disease Control and Prevention's Behavioral Risk Factor Surveillance System are based on samples too small to produce stable smoking prevalence estimates in Texas. The data should be accumulated across years and/or the sample increased to provide more stable estimates.

(11) ***Disseminate information on cancer, its causes and its prevention, to the public through educational courses and media reports.*** The strengths and limitations of scientific methods in studying cancer should also be conveyed.

A CRITICAL REVIEW OF CANCER IN TEXAS:
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1.0 INTRODUCTION

1.1 Background and Rationale

Cancer is the second leading cause of death in Texas and in the U.S. and has held this rank since 1950. In 1992, malignant neoplasms killed 29,995 Texans, 23% of all deaths (Cancer Registry Division, 1993). An economic analysis of the direct and indirect costs estimated that cancer in Texas cost $4.4 billion in 1988, more than an 80% increase in cancer costs since 1980 (Williams and Begley, 1992). The large petrochemical complex along the Gulf Coast as well as other environmental and occupational exposures have been considered by some as possibly major contributing factors to the burden of cancer in Texas. These concerns exist in a national milieu of controversy over trends in cancer mortality and the possible contribution of environmental exposures to the burden of cancer. In response to these concerns, the Texas Institute for Advancement of Chemical Technology (TIACT) solicited proposals to review critically the published, as well as the unpublished epidemiologic literature in the public domain, to determine what is known about the cancer burden in Texas, to identify gaps in existing data, and to recommend further studies. The emphasis of this report was on the possibility of estimating the role of environmental and occupational exposures in relation to cancer. The University of Texas-Houston School of Public Health was selected to conduct this project.

Historically, excess rates of cancers of bladder, liver, lung, skin, brain, and all lymphopoietic tissue have been reported in Texas, particularly in counties along the Gulf Coast (Hoover and Fraumeni, 1975; Buffler, 1978; Riggan and Mason, 1983; Pickle et al., 1987). Although an exclusively male excess would be suggestive of an occupational etiology, many of the excesses noted in Texas have been reported among females as well.

In response to these and other excesses reported in the literature or suggested by plant workers, over 100 occupational and environmental epidemiologic studies have been conducted in Texas. Conclusions by authors about even the same study populations have sometimes varied. A systematic review and synthesis is required for some interpretation of these studies, due to their differences in study design, sample size, comparison populations, assessment of exposure, length of follow-up, and overlap in study populations.

In this report, cancer mortality, over time and geographically within the state, is presented to provide a background and perspective for the critical review of the epidemiologic studies about cancer in Texas. A systematic search and critical review of the published and unpublished epidemiologic literature pertaining to cancer in Texas is assessed, taking into account the scientific merit of each study. The studies will be discussed and summarized according to a classification of industrial population studies (by study design or special focus on a particular cancer type) and population and hospital-based studies (by exposure and cancer type). Further,

summary measures of risk by cancer type and plant type (refinery, chemical manufacturing, mixed) were calculated for a non-overlapping subset of the industrial cohort mortality studies. Inferences about the relative impact of environmental and occupational exposures are made and gaps in current data identified. An overview of epidemiologic study designs is included in Appendix A. To the authors' knowledge, this report represents the first attempt to assemble comprehensively and evaluate critically the epidemiologic studies on cancer in Texas.

1.2 Specific Aims

This study aimed to answer the following questions:

1. How great is the burden of cancer in Texas compared to the U.S., how has it changed in recent time, and how does it vary by geographic region within the state?
2. What is known about the contribution of environmental and occupational factors, as well as lifestyle and genetic factors to this burden and its variation in Texas?
3. What major data gaps exist in the evidence currently available about cancer in Texas and what further studies are recommended?

1.3 Mortality Analyses: Data Sources and Analytic Methods

Aim 1, concerning the magnitude of the cancer burden in Texas and its variation over time and geographic area, is addressed on the basis of statewide mortality data for cancer. Unless otherwise noted, cancers were all coded to the Ninth Revision of the International Classification of Diseases (ICD) (categories listed in Table B-1, Appendix B). The mortality experience is presented in terms of three perspectives:

(1) The comparison of average annual age-adjusted cancer mortality rates in Texas vs. the U.S. was undertaken to identify those cancer sites with rates significantly higher or lower than the rates in the U.S. over the same time period, 1986-1990.

(2) The trends in mortality rates over 1980-1990 for Texas and the U.S. are presented to compare the Texas cancer experience over an 11-year period of time with that of the United States.

(3) Regional differences and similarities in cancer mortality were assessed within Texas by means of standardized mortality ratios (SMRs) and trends in rates over time within 24 areas of Texas (Appendix C).

In all cases, data available from the Cancer Registry Division, Texas Department of Health, or from national published data were used for the analyses. These three approaches were taken to describe cancer mortality patterns and to answer the following questions:

- Which cancers in Texas have higher or lower rates when compared to the U.S.?
- Are there cancers which have been increasing or decreasing in recent time in Texas? If so, is this similar or dissimilar when compared to the U.S.?
- Within Texas, are there areas where cancers have been increasing or decreasing over time?
- Within Texas, are there areas where cancer rates are higher or lower than the expectation based on Texas as a whole?

1.3.1 *Texas vs. U.S. Cancer Mortality Rates*

Seventeen cancer sites, which represented 79.8% of all cancer deaths for Texas over the years 1986-1990, were selected to include the most frequent cancers and also those possibly related to environmental or occupational exposure. Average annual age-adjusted cancer mortality rates for Texas and the U.S. covered the years 1986-1990, which were the most recent five years available from the National Cancer Institute SEER data (Miller et al., 1993). Only non-Hispanic whites (Anglos) and blacks are compared to U.S. whites and blacks because national cancer mortality rates for Hispanics (primarily Mexican-Americans in Texas) were unavailable.

Texas Hispanic average annual age-adjusted mortality rates for 1986-1990 by cancer site for males and females are compared to average annual age-adjusted mortality rates for California Hispanics, 1988-1990 (Perkins et al., 1993). This was selected as the most comparable population, although differences, other than residence in Texas, may exist for California Hispanics (e.g., country of origin, environmental and occupational exposure, lifestyle). Mortality patterns vary among Hispanic populations; therefore California Hispanics provided a more appropriate comparison group since they, like Texas Hispanics, are predominantly Mexican-Americans. The comparison years differed slightly between the two states; only 1988-1990 was available for California.

Mortality rates in Texas for 1986-1990 were obtained from the Cancer Registry Division, Texas Department of Health. The Texas Department of Health utilized population estimates (denominator of rates) provided by the Bureau of State Health Data and Policy, which were updated based on the 1990 census. The Hispanic classification for the population was based on the U.S. Bureau of the Census Spanish origin; however, Hispanic designation for the mortality data (numerator) was based on Spanish surname, as determined by the Generally Useful Ethnic Search System (GUESS). A review by the Texas Department of Health indicated that Spanish origin population estimates are greater than those based on Spanish surname, the impact of which is to slightly underestimate Hispanic rates. However, the magnitude of this effect is believed to be quite small. Comparisons using both methods have affected counts by less than five percent (personal communication, Texas Department of Health).

The detection of significant differences in cancer mortality rates was accomplished by the method outlined below. Standard errors of the rates for statistical testing were approximated for the U.S. and Texas by the following formula:

$$SE(rate) = \text{mortality rate}/[\text{deaths}]^{1/2} \qquad \text{(Miller et al., 1993)}$$

The standard errors for rates in California Hispanics were provided in Cancer Incidence and Mortality by Race/Ethnicity in California, 1988 - 1990 (Perkins et al., 1993).

Tests of significance for comparing differences in mortality rates between Texas and the U.S. (or California for Hispanics) were calculated by:

$$Z = (Rate_{TX} - Rate_{CA})/SE_{dif} \qquad \text{or} \qquad Z = (Rate_{TX} - Rate_{US})/SE_{dif}$$

where

$Rate_{TX}$ was the Texas age-adjusted rate, $Rate_{CA}$ was the California age-adjusted rate, $Rate_{US}$ was the U.S. age adjusted rate, SE_{dif} was:

$$SE_{dif} = [(SE_{TX})^2 + (SE_{CA})^2]^{1/2} \quad \text{or} \quad SE_{dif} = [(SE_{TX})^2 + (SE_{US})^2]^{1/2}$$

A "Z" score greater than or less than 1.96 was considered significant at $p < 0.05$. An alternate method used to compare rates was to compare the ratio of the two rates, rather than the difference (Rothman, 1986). The results using the rate ratio method were in agreement with the rate difference method, and are not presented here.

1.3.2 *Cancer Mortality Trends in Texas, 1980-1990*

Unpublished mortality data from 1980-1990 for the same 17 cancer sites (ICD-9th Revision) were obtained from the Cancer Registry Division of the Texas Department of Health. Annual Texas mortality rates were directly age-adjusted to the 1970 U.S. population (in 18 five-year age groups). By the application of a test for linear trend (Snedecor and Cochran, 1967) the significantly increasing and decreasing rates over the 11-year period were identified by sex/race/ethnic group.

These 17 cancer sites were then compared to U.S. rates over the same time period, 1980-1990. National Cancer Institute SEER data from the Cancer Statistics Review, 1973-1990 were abstracted for the pertinent years and a test for trend applied. Since only rates were available by year, the method used by SEER to calculate the Estimated Annual Percent Change (EAPC) was employed (Miller et al., 1993). Thus, the testing for trend in the U.S. rates was accomplished by fitting a regression line to the natural logarithm of the rates using calendar year as a regressor variable. This can be expressed by:

$$Y = mx + b$$

where $Y = \ln(\text{rate})$

x = calendar year.

The EAPC was calculated by:

$$EAPC = 100 * (e^{m}-1)$$

The null hypothesis, that the slope (m) of the line was equal to zero was equivalent to testing EAPC was equal to zero. The test was computed by dividing the slope by its standard error which is a statistic that follows the "t" distribution with the number of degrees of freedom equal to the number of calendar years minus two. The slope and standard error were obtained from fitting the regression line. The Texas trends may be assessed visually in text figures and in Appendix D against the backdrop of the U.S. experience.

To examine time trends within Texas, age-adjusted rates over 1976-1989 within 24 geographic regions known as Councils of Government (COG) were each separately evaluated by the test for linear trend (Snedecor and Cochran, 1967) mentioned above. These geographic divisions encompass the entire state and are based on state planning regions. A map designating these 24 COGs and a list of counties within each COG is included in Appendix C. The time span for these analyses was somewhat different than for the data presented for the entire state (1980-1990) because computer runs for this extensive analysis were already available from the Cancer Registry Division, Texas Department of Health. Due to the inclusion of the earlier years, population estimates were based on the 1980 census, Hispanic deaths and population were classified based on Spanish surname, and cancers were all coded to the Eighth Revision of the ICD. However, these differences should not affect these analyses since the comparisons were made within sex/race/ethnic groups and cancer sites. To determine if any significantly increasing or decreasing trends also occurred prior to 1976, the National Cancer Institute/Environmental Protection Agency publication by Riggan and Mason (1983) was reviewed to determine if 1) the trend seen in the TDH data was a continuation of an increase or decrease evident in the years 1950 through 1979 or 2) the trend seen in the TDH data was a reversal or change in the prevailing situation documented for the years 1950 through 1979. Limitations of this method were that Riggan and Mason reported rates by county (not COG) and Hispanics were included as white, thus the only comparisons possible were for white and non-white. For each COG, rates (based on counties with the largest population centers) were considered to have been generally increasing, decreasing, stable or inadequate for any conclusion over the 30 years encompassed by Riggan and Mason (1983).

1.3.3 *Geographic Variation in Cancer Mortality*

In addition to time trends, overall geographic excesses were assessed by examining standardized mortality ratios (SMRs) for each state planning region or COG. The sex/race/ethnic specific rates of Texas as a whole were used by the Cancer Registry Division, Texas Department of Health to calculate the expected number of deaths for each sex/race/ethnic group by cancer site for each COG for the combined years 1980-1991. To maintain consistency with most of the cohort mortality studies, SMRs were multiplied by 100 for presentation throughout this report. The rate for a given sex/race/ethnicity/cancer site was considered to have been a relative excess

or a deficit if three criteria were met: 1) The 95% confidence interval of the SMR excluded one hundred; 2) The SMR was equal to or greater than 120 or, conversely, the SMR was equal to or less than 83 (for a ratio measure of association, the equivalent protective value is equal to the reciprocal of the relative risk value, thus, the reciprocal of 120 is 83); and 3) at least 12 deaths must have occurred within the 12 year time period, or roughly one death per year.

The criteria were decided upon with the general aim that relative excesses or deficits should be of a magnitude perceived to be meaningful, and with some statistical stability. The SMR for each COG by sex/race/ethnicity/cancer site will vary when compared to Texas as a whole and it is difficult to say when the deviation becomes meaningful. The impact of using a cut-off of 30% or 50% might be to obscure important deficits or excesses. Therefore a 20% cut-off (≤ 83 or ≥ 120) appeared to be a reasonable, albeit arbitrary choice. The 95% confidence level is a standard choice and was the significance level computed by the Cancer Registry Division. A twelve death minimum over the 12 year period was elected primarily to provide some stability to the SMR estimates.

In the event that conclusions based on the regional cancer experience in Texas would have been different had the 10% cut-off been used, Table E-3, containing these cancer sites by sex/race/ethnicity/COG as well as the SMRs and 95% confidence intervals (retaining criteria for statistical significance and a minimum of 12 deaths), is presented in Appendix E.

1.4 Critical Review of the Literature

Aim 2, concerning the current knowledge about the contribution of environmental and occupational, as well as lifestyle and genetic factors, to cancer in Texas is addressed by a critical review of the published and unpublished epidemiology literature regarding cancer in Texas. Eligibility requirements, searching procedures, exclusions, and evaluation criteria are described below.

1.4.1 *Eligibility Requirements for Critical Review*

For a study to be eligible to be included in this critical review, a set of requirements was developed as listed below:

1. Only human epidemiologic reports were included.
2. All study data collection must have been completed prior to initiation of the TIACT Request for Proposal; specifically, no later than September, 1992.
3. The study had to be in the time frame of the computerized literature search (the earliest database began in 1964).
4. The study must be publicly accessible, although not necessarily published.
5. The authors and their affiliation must have been identified.
6. The study had to be conducted in a Texas population.
7. The study must pertain to exposures and cancer. (Articles pertaining only to cancer rates without exposure data or to exposures without cancer data were not

included, although these were considered in the overall assessment of cancer in Texas.)

8. The study must have been in the form of a written report (i.e., not raw data) where the documentation included exposure, health status, study methods, statistical analyses, and interpretation by the authors.

1.4.2 *Computerized Library Search*

A complete computerized library search of major databases relevant to epidemiologic studies of cancer in Texas was performed. The following computerized databases were searched:

1.	MEDLINE	MESH	1988-1993
		MESZ	1966-1987
2.	CANCERLIT:	CANR	1975-1993
3.	NIOSHTIC:		1973-1993
4.	BIOSIS:	BIOZ	1970-1993
5.	EMBASE - Excerpta Medica:		
		EMEZ	1974-1993
6.	TOXLINE	TOXL	1965-1992
		TX93	1993-present
7.	RTECS		current with quarterly updates
8.	CHEMINFO		current with periodic updates
9.	NTIS		1964-1993
10.	Chemical Industry Notes		1974-1993
11.	Conference Papers Index		1973-1993
12.	Theses and Dissertations from The University of-Texas Houston School of Public Health		

1.4.3 *Other Sources of Unpublished Reports*

In addition to the computerized databases, the scope of the search for unpublished reports included the following:

1. Solicitation of major chemical/petrochemical companies through TIACT
2. Solicitation of TIACT Steering Committee members for Cancer in Texas Study
3. Solicitation of major environmental groups and labor unions (Texas Center for Policy Studies, Sierra Club, Environmental Defense Fund, Pesticide Education Center, National Audubon Society, Citizens Environmental Coalition, Farm Worker Justice Fund, Texans United, Greenpeace, OCAW, AFL-CIO)

1.4.4 *Exclusion of Clinical Case Series and Cancer Cluster Investigations*

Due to their lack of correspondence to any definable population, this review did not include published clinical series reports or cancer cluster investigations conducted by the Cancer

Registry Division or the Noncommunicable Disease Epidemiology and Toxicology Division at the Texas Department of Health. A cancer cluster is an unusual grouping of cancer in time and/or space and investigations are often initiated based on citizen concerns. While the Texas Department of Health can determine if the cancer rates in a particular area are higher than expected, relating the cancers to a specific cause (e.g., a particular environmental or occupational exposure) is typically limited to weak or only suggestive inferences. That is, for example, in the 241 investigations conducted by the Cancer Registry Division of possible cancer excesses in Texas since 1986, the investigations served better to generate hypotheses for more scientifically rigorous study than to add substantially to conclusions about causation.

1.4.5 *Criteria for Evaluating Studies*

The following features, which address issues of study design, bias, confounding, chance, and causal inference, were used to evaluate critically each study included in this review:

- study design
  (Was the study design one without a population at risk, such as a proportionate mortality ratio study, or an analytic one, such as a cohort or case-control study?)
- assessment of exposure
  (Was the exposure based on crude surrogates such as ever/never employed or on more precise measures based on industrial hygiene monitoring?)
- assessment of cancer
  (How was cancer ascertained--from company records, death certificates, or confirmed through pathologic diagnosis?)
- selection of cohort or cases
  (How was the cohort defined in a cohort study or cancer cases selected in a case-control study?)
- selection of comparison group (unexposed or controls)
  (How was the unexposed group defined in a cohort study (e.g., U.S., Texas, internal comparison), or the comparison group selected in a case-control study?)
- sample size and power
  (Was the sample size adequate to yield stable measures of association?)
- statistical analysis
  (Was the statistical analysis appropriate for the study design?)
- completeness of follow-up
  (In cohort studies, how complete was the vital status and death certificate ascertainment?)
- confounding factors
  (Were other factors also related to exposure and cancer adequately addressed in the design or analysis?)
- latency
  (Had sufficient time elapsed between exposure and study follow-up for disease outcome to account for the long latency of cancer?)
- dose-response relationship

(Did the risk of cancer increase with increasing exposure?)

- other sources of bias
  (What factors, other than the exposures of interest, may have influenced the results and in what direction?)

1.5 Description of Studies Reviewed

Based on the computerized library searches and solicitation of other published and unpublished reports, 136 studies that met the specified eligibility requirements were available for review. No studies were excluded based on the study data collection eligibility requirements. Only one study was excluded based on the time frame of the computerized literature search. This study (Lewis et al., 1994), however, was noted and discussed in relation to earlier similar studies. No epidemiologic studies were received from the environmental groups and labor unions (either no studies were conducted or no response was made), although studies conducted by NIOSH on labor union populations, have been published and included in this review. We critically reviewed all 136 studies reported from 1964-1993. It should be noted that in some instances, a single study population was addressed in more than one of these 136 reports, so that the individual reports are not entirely independent. Table 1 displays the distribution of the reviewed reports by type of exposure, study design, source of the study, publication status, and year of publication.

The exposure variables were categorized as "occupational" when they were encountered in the context of an employment setting. "Environmental" refers to ambient, or non-occupational exposures (e.g. water, air). "Genetics" refers to apparent heritable factors associated with the cancer(s) of interest. "Lifestyle" refers to personal habits such as diet, smoking, and exercise, which are for the most part elective. The studies are characterized as case-control, historical cohort, ecological, cross-sectional, proportionate mortality ratio, according to acceptable epidemiologic nomenclature (see Appendix A). The "source of study" refers to the institutional affiliation of the lead author. "Published" refers to publication of the article in a peer-reviewed scientific journal.

Three-fourths of the articles pertained to cancer and occupational exposures compared with less than 5% to lifestyle exposures (e.g. diet, exercise). Likewise, approximately three-fourths of the reviews covered historical cohort and case-control studies (about evenly split between the two study designs). Half of the studies were conducted by authors based at academic institutions, one-third conducted by industry, and the remaining 16% by government agencies. Nearly three-fourths of the reports were published in peer-reviewed scientific journals (n=101) and the remainder were in-house reports (n=9) or unpublished masters theses or doctoral dissertations (n=26). Twenty-five of these theses and dissertations were contributed by The University of Texas-Houston School of Public Health. There was an interesting increase in the number of reports over the past 30 years covered by this study. Only 2 studies were reported prior to 1974 compared to 40% (n=55) reported during 1974-1983 and 58% (n=79) reported in the most recent 10 year period.

Table 1
Distribution of Reviewed Reports by
Type of Exposure, Study Design, Source of Study,
Publication Status, and Year of Report

Type of Exposure	n	%
1. Occupational	102	75.0
2. Environmental	20	14.7
3. Genetic	7	5.1
4. Lifestyle	6	4.4
5. Other	1	0.7
	136	100.0

Study Design	n	%
1. Historical Cohort	51	37.5
2. Case-control	52	38.2
3. Cross-sectional	10	7.4
4. Ecological	15	11.0
5. Other (Mainly PMR)*	8	5.9
	136	100.0

Source of Study	n	%
1. Academic	69	50.7
2. Industry	45	33.1
3. Government	22	16.2
	136	100.0

Publication Status	n	%
1. Yes	101	74.3
2. No	35	25.7
	136	100.0

Year of Report	n	%
1. 1964-73	2	1.5
2. 1974-83	55	40.4
3. 1984-93	79	58.1
	136	100.0

* Six of these were PMR studies; 2 were case-series related to the PMR and follow-up cohort investigations of brain tumors.

2.0 CANCER MORTALITY IN TEXAS

2.1 Texas Cancer Mortality Rates Compared to the U.S.

As shown in Table 2, in general, most of the average annual age-adjusted mortality rates by cancer site were less or nearly equal for Texas (1986-1990) when compared to the U.S. (1986-1990). The most notable deficits were for colon and rectum cancer among white males and females, breast cancer among white females, and prostate cancer among black males. However, liver cancer mortality rates per 100,000 population per year were significantly higher in all race/sex groups, except black females. Lung cancer was significantly elevated in Texas white males and white females and significantly lower in black females. Texas kidney cancer mortality rates were significantly higher in black males when compared to the U.S. For both Texas and the U.S., cancer rates were generally higher among black males compared to white males with the exception of brain cancer, non-Hodgkin's lymphoma, and leukemias. The same pattern held for females except that white female lung cancer and ovarian cancer mortality rates exceeded black female rates.

Average annual age-adjusted mortality rates for 1986-1990 in Texas were compared to rates for California Hispanics (1988-1990) by cancer site and sex in Table 3. Texas and California Hispanic cancer mortality rates, albeit for slightly differing time periods, were similar with the following exceptions. Texas Hispanic females had significantly lower rates for stomach and rectum cancer. Liver cancer mortality rates among Texas Hispanic males and females were significantly higher than the rates in California. This elevation of liver cancer parallels the higher rates of liver cancer observed for Texas whites and black males. Additionally, pancreas cancer was elevated for Texas Hispanic females vs. California females. Lung cancer in Texas Hispanic men was notably and significantly higher and cervix cancer was statistically elevated in Texas Hispanic women compared to California Hispanic women. Total cancer mortality rates were higher for Texas Hispanic males and females when compared to California. In comparing Tables 2 and 3, cancer mortality rates were notably lower among Hispanics in Texas and California than whites and blacks, except for stomach, liver, and gallbladder cancer. These ethnic differences have been well documented in the literature (Newell and Mills, 1987; Suarez and Martin, 1987; Lee et al., 1976; Martin and Suarez, 1987; Bornstein, 1970) which have in part been attributed to differences in smoking patterns (Martin and Suarez, 1987), diet, social class, and lifestyle (Newell and Mills, 1987). Regional standardized mortality ratios (SMRs) are presented in Section 2.3 in which local variation of rates of specific cancer sites, as compared to Texas as a whole, are explored.

2.2 Cancer Mortality Trends in Texas, 1980-1990

2.2.1 *Overall Cancer Mortality Trends*

As shown in Table 4 and Figure 1, age-adjusted total cancer mortality rates over the years 1980-1990 were seen to be significantly increasing for Anglo males and Anglo females, Hispanic males and black males in Texas. This experience was similar to the nation over the same time

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Table 2

AVERAGE ANNUAL AGE-ADJUSTED CANCER MORTALITY RATES[a]
AND STANDARD ERRORS FOR SELECTED SITES BY SEX AND ETHNICITY IN TEXAS,
1986-1990, AND THE U.S., 1986-1990

	WHITE[†] MALES				WHITE[†] FEMALES				BLACK MALES				BLACK FEMALES			
	Texas		U.S.		Texas		U.S.		Texas		U.S.		Texas		U.S.	
Cancer Site	Rate	SE[#]	Rate	SE[#]	Rate	SE[#]	Rate	SE[#]	Rate	SE[#]	Rate	SE[#]	Rate	SE[#]	Rate	SE[#]
Stomach	4.9*	0.14	6.4	0.03	2.4*	0.08	2.8	0.02	12.1*	0.62	13.7	0.17	5.2	0.33	5.6	0.09
Colon[b]	17.4	0.26	-	-	12.0	0.18	-	-	25.5	0.90	-	-	17.6	0.61	-	-
Rectum[b]	2.1	0.09	-	-	1.2	0.06	-	-	3.0	0.31	-	-	1.6	0.18	-	-
Colon & Rectum	19.5*	0.26	23.8	0.07	13.2*	0.19	16.0	0.04	28.5	0.95	28.0	0.24	19.2*	0.64	20.6	0.17
Liver, Bile Duct	4.1*	0.12	3.5	0.03	2.0*	0.07	1.7	0.02	7.2*	0.47	6.2	0.11	2.8	0.25	2.5	0.06
Gallbladder, Biliary[c]	1.0	0.06	1.3	-	1.1	0.05	1.5	-	0.8	0.16	1.1	-	1.2	0.16	1.3	-
Pancreas	9.4	0.19	9.7	0.04	6.3*	0.13	6.9	0.03	13.8	0.66	14.2	0.17	9.7	0.46	10.3	0.12
Lung, Bronchus	77.2*	0.55	72.9	0.12	31.4*	0.31	29.8	0.07	107.1	1.86	105.1	0.47	27.1*	0.80	29.4	0.21
Breast	0.2	0.03	0.2	0.01	23.8*	0.27	27.3	0.06	0.4	0.12	0.4	0.03	28.2*	0.79	30.8	0.21
Cervix	-	-	-	-	2.2*	0.08	2.6	0.02	-	-	-	-	6.6	0.38	6.9	0.10
Ovary	-	-	-	-	6.9*	0.14	8.0	0.03	-	-	-	-	6.4	0.38	6.4	0.10
Prostate	20.5*	0.28	23.1	0.07	-	-	-	-	44.3*	1.19	50.7	0.33	-	-	-	-
Bladder	4.8*	0.14	5.8	0.03	1.4*	0.06	1.6	0.01	4.4	0.37	4.7	0.10	2.1	0.21	2.4	0.06
Kidney, Urin. Sys.	5.2	0.14	5.2	0.03	2.3	0.08	2.4	0.02	6.2*	0.43	5.1	0.10	2.5	0.24	2.4	0.06
Brain, Nervous System	5.2	0.14	5.3	0.03	3.6	0.11	3.6	0.02	3.2	0.31	3.2	0.08	2.3	0.22	2.1	0.05
Non-Hodgkin's Lymphoma	7.1*	0.16	7.7	0.04	4.5*	0.11	5.1	0.03	4.7*	0.37	5.6	0.10	2.9	0.25	3.1	0.06
Multiple Myeloma	3.3	0.11	3.3	0.02	2.1	0.07	2.2	0.02	7.1	0.48	7.1	0.12	4.2	0.30	4.8	0.08
Leukemias	8.8	0.18	8.5	0.04	5.0	0.12	4.9	0.03	7.8	0.47	7.9	0.12	5.1	0.33	4.7	0.08
ALL SITES[d]	212.0	0.90	213.2	0.20	132.1*	0.61	139.2	0.14	307.2*	3.12	315.0	0.81	157.1*	1.87	165.7	0.48

SOURCE: 1) Unpublished data, Cancer Registry Division, Texas Department of Health
2) SEER, Cancer Statistics Review, 1973-1990: Table I-6 and A-2 (Miller et al., 1993)

a) Rates are per 100,000 age-adjusted to the 1970 U.S. Standard population
b) Data for colon and rectum cancer available only in the aggregate for the U.S.
c) Data not available to calculate standard error
d) Includes all cancer sites, not only ones selected for inclusion in this table.
[†] White, non-Hispanic for Texas, white for US; National Hispanic (Mexican-American) rates unavailable.

*) Difference in rates significant at $p < 0.05$
#) SE-Standard Error, approximated by SE = rate/(number of deaths)$^{1/2}$

Table 3

AVERAGE ANNUAL AGE-ADJUSTED CANCER MORTALITY RATES* IN HISPANICS FOR SELECTED SITES BY SEX IN TEXAS, 1986-1990, AND CALIFORNIA, 1988-1990

	HISPANIC MALES				HISPANIC FEMALES			
	Texas		California		Texas		California	
Cancer Site	Rate	SE	Rate	SE	Rate	SE	Rate	SE
Stomach	9.4	0.42	9.1	0.47	4.0*	0.24	4.9	0.29
Colon	9.9	0.42	9.7	0.50	5.6	0.29	6.3	0.34
Rectum	2.1	0.20	2.7	0.26	0.7*	0.01	1.3	0.16
Liver, Bile Duct	8.0*	0.40	5.3	0.36	3.8*	0.24	2.9	0.24
Gallbladder, Biliary	1.6	0.18	1.5	0.20	2.9	0.21	3.0	0.23
Pancreas	8.3	0.40	7.8	0.44	6.1*	0.31	5.1	0.31
Lung	39.3*	0.89	29.4	0.87	10.6	0.40	10.5	0.44
Breast	0.1	0.04	0.0	0.03	14.9	0.46	14.6	0.50
Cervix					4.3*	0.24	3.6	0.24
Ovary					4.5	0.26	4.8	0.29
Prostate	12.7	0.52	14.0	0.62				
Bladder	2.0	0.20	2.2	0.25	1.0	0.12	0.8	0.12
Kidney, Urinary Syst.	4.2	0.28	3.6	0.30	2.4	0.19	1.9	0.19
Brain, Nervous System	2.9	0.21	3.5	0.28	2.0	0.16	1.7	0.17
Non-Hodgkin's Lymphoma	4.8	0.29	4.8	0.34	3.8	0.23	3.3	0.24
Multiple Myeloma	2.6	0.23	2.9	0.26	1.5	0.15	1.9	0.19
Leukemias	5.4	0.28	5.3	0.33	3.7	0.22	3.3	0.23
ALL SITES†	139.8*	1.63	122.9	1.75	88.9*	1.13	84.7	1.22

SOURCE: 1) Unpublished data, Cancer Registry Division, Texas Department of Health
2) Cancer Incidence and Mortality by Race/Ethnicity in California, 1988-1990; Table 5, Page 116, and Table 6, Page 127 (Perkins et al., 1993)

*Rates are per 100,000 per year adjusted to the 1970 U.S. Standard population.
*Rate significantly different, $p < 0.05$
†Includes all cancer sites, not only the ones selected for inclusion in this table.

Table 4

Significant Trends in Texas Mortality Rates for Selected Cancer Sites by Ethnicity and Sex, 1980 to 1990

	Females			Males		
Site/Type	Anglo	Black	Hispanic	Anglo	Black	Hispanic
Stomach	-	-	-	-	-	-
Colon	-	-	-	-	↑	↑
Rectum	-	-	-	-	-	-
Liver	-	-	-	↑	-	↑
Gallbladder	-	-	-	-	-	-
Pancreas	-	-	-	-	-	-
Lung, Bronchus	↑	↑	-	-	↑	↑
Breast	-	-	-	-	-	-
Cervix	-	-	-	-	-	-
Ovary	-	-	-	-	-	-
Prostate	-	-	-	-	↑	-
Bladder	-	-	-	-	-	-
Kidney	-	-	-	-	-	-
Brain, Nervous System	-	-	-	-	-	-
Non-Hodgkin's Lymphoma	-	-	↑	-	-	-
Multiple Myeloma	-	-	-	-	-	-
Leukemias	-	-	-	-	-	-
ALL SITES#	↑	-	-	↑	↑	↑

Legend: ↑ = Significant increasing trend, $p<0.05$
↓ = Significant decreasing trend, $p<0.05$
- = No significant trend

Includes all cancer sites, not only the ones selected for inclusion in this table.

Source: Unpublished data, Cancer Registry Division, Texas Department of Health

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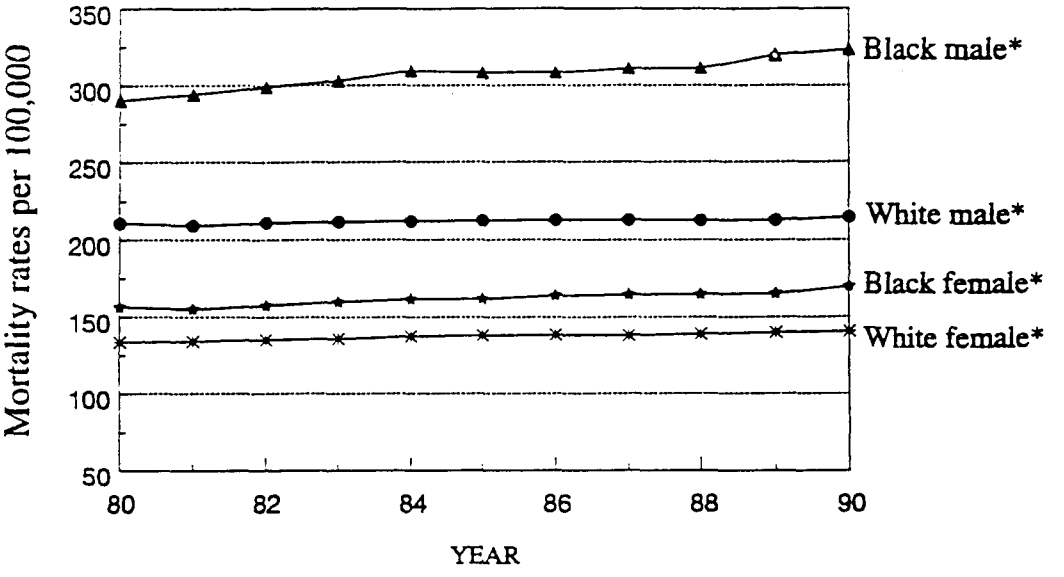
FIGURE 1

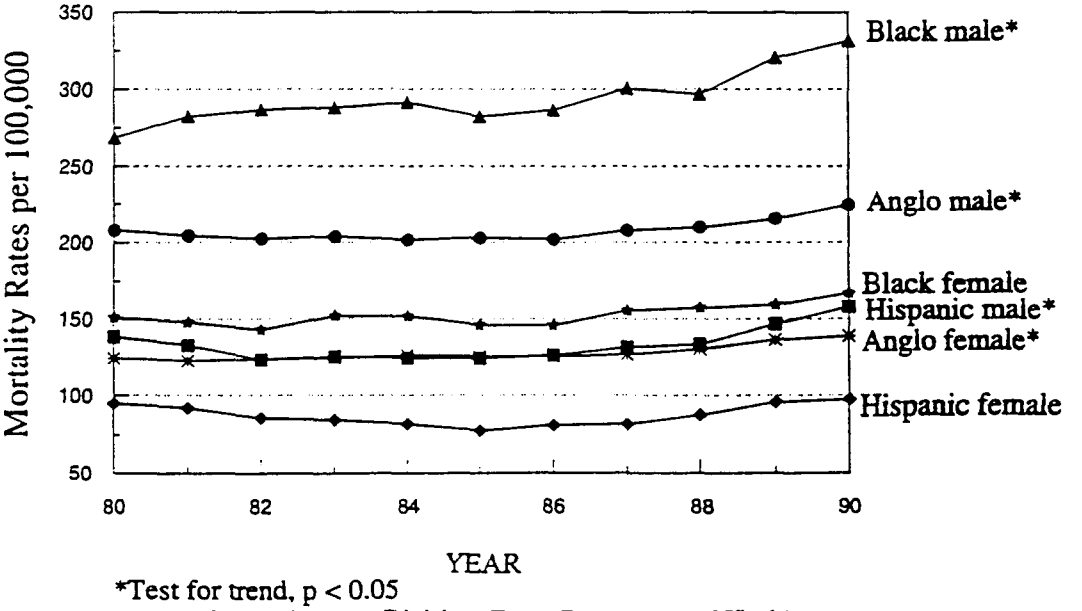
Age-Adjusted Total Cancer Mortality in the U.S. by Race and Sex, 1980-1990



*Test for trend, $p < 0.05$

Source: SEER, Cancer Statistics Review, 1973-1990

Age-Adjusted Total Cancer Mortality in Texas by Race/Ethnicity and Sex, 1980-1990



*Test for trend, $p < 0.05$

Source: Cancer Registry Division, Texas Department of Health

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period as can also be seen in Figure 1. Most of this increase was accounted for by lung cancer (Table 4 and Figure 2). Most cancer sites exhibited stable rates in Texas over the 11 year period with the following exceptions. Texas lung cancer mortality rates for 1980-1990 were significantly increasing in Anglo females, black females, black males and Hispanic males as shown in Figure 2. The rates of lung cancer for the U.S. were also significantly increasing in these groups during these years. Texas mortality rates for liver cancer increased significantly among Anglo and Hispanic males. Again, Texas mirrored the U.S. increase in liver cancer seen in white males (Appendix D). Colon cancer mortality rates also increased in Texas black and Hispanic males as well as non-Hodgkin's lymphoma among Hispanic women and prostate cancer among black males. Colon cancer mortality rates in the U.S. were not available separately for comparison, but were combined with rectum cancer. Data for colorectal, as well as prostate cancer, in black males in the U.S. revealed a significantly increasing trend over the years 1980-1990.

The figures in Appendix D present the age-adjusted mortality rates for seventeen cancer sites (other than total and lung shown in Figures 1 and 2) by sex/race/ethnicity in Texas juxtaposed with the U.S. rates over 1980-1990. The Texas rates were much more variable, reflecting instability from smaller population sizes. Increasing and decreasing trends, if present, in the U.S. data were more likely to be statistically significant, again a reflection of the relative stability of the rate estimates.

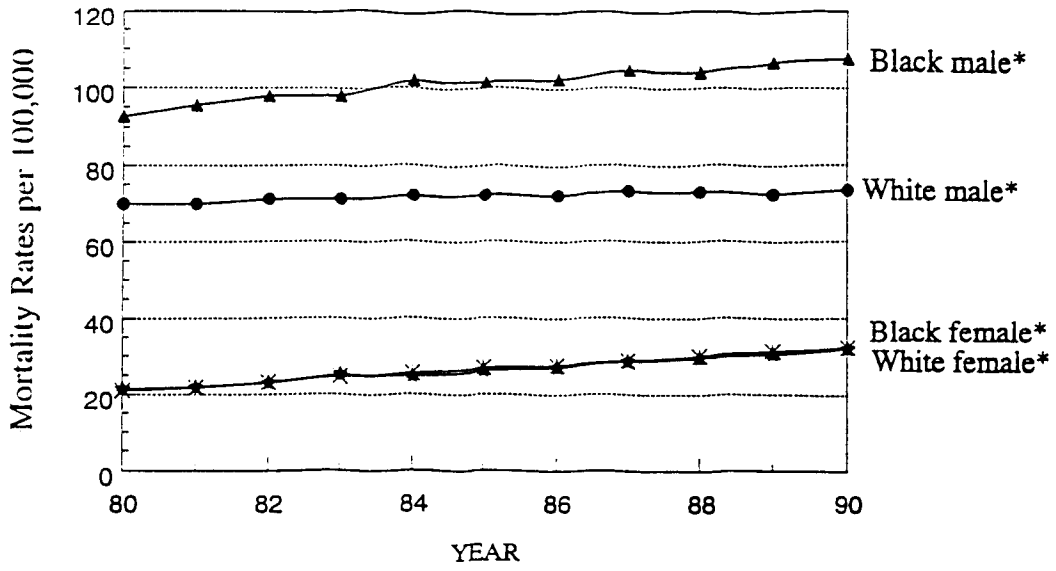
2.2.2 *Geographic Variation in Cancer Mortality Trends*

Decreasing and increasing trends for 1976-1989 were mapped by the 24 Councils of Governments (COGs) and cancer type in Figure 3. In all cases, trends remained the same as reported for earlier time periods (1950-1979) by Riggan and Mason (1983). Figure 3 is most notable for the lack of significantly increasing or decreasing trends. Statistically significant decreasing trends in cancer mortality rates between 1976 and 1989 (left map of Figure 3) were seen in Anglos and Hispanics, but not in blacks. Hispanic females experienced a decrease in cancer of the pancreas and Hispanic males had less bladder cancer over time in the Panhandle region of Texas. In the region of Texas that includes the Dallas-Ft. Worth metropolitan areas, Anglo males and females experienced decreases in stomach and cervical cancer, respectively and Hispanic males had a reduction over time for cancer of the gallbladder. Stomach cancer in Hispanic males and cervical cancer in Hispanic females significantly decreased over time in the Houston/Harris County metropolitan area of the state.

Significant increasing trends in cancer mortality rates for 1976 to 1989 (right map of Figure 3) and for 1950-1979 as published by Riggan and Mason (1983) were dominated by lung cancer. Anglo females were the sex/ethnic group in which this trend was most apparent and increasing trends in this ethnic group occurred in seven regions of Texas. Increases in lung cancer deaths over time in other race groups occurred within two regions, areas that include Dallas-Ft. Worth (black females) and Houston (black males and black females). Black males also experienced a significant increase in cancer of the large intestine in the region that includes Houston (Harris County).

FIGURE 2

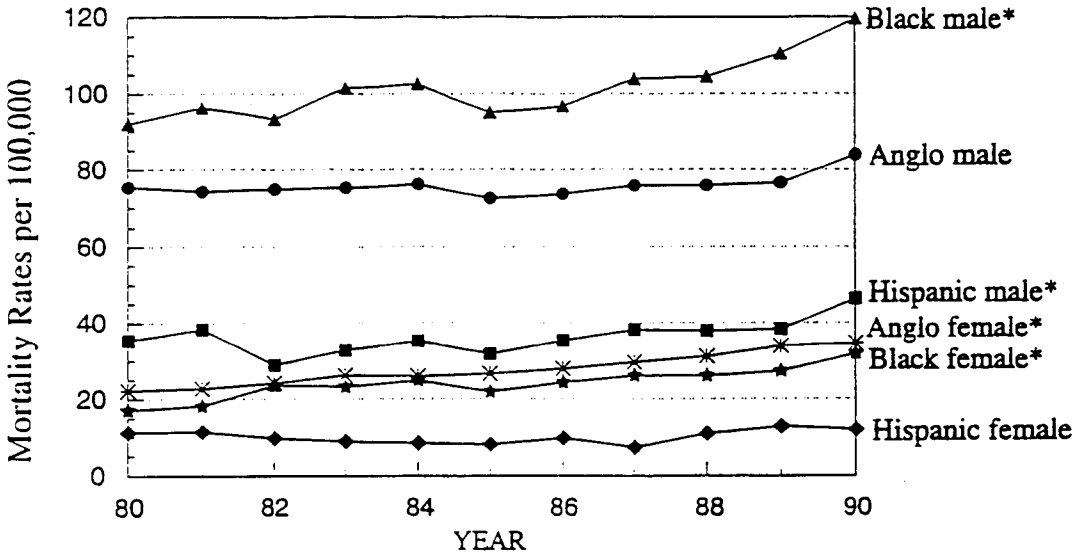
Age-Adjusted Lung Cancer Mortality in the U.S. by Race and Sex, 1980-1990



*Test for trend, $p < 0.05$

Source: SEER, Cancer Statistics Review, 1973-1990

Age-Adjusted Lung Cancer Mortality in Texas by Race/Ethnicity and Sex, 1980-1990



* Test for trend. $p < 0.05$

Source: Cancer Registry Division, Texas Department of Health

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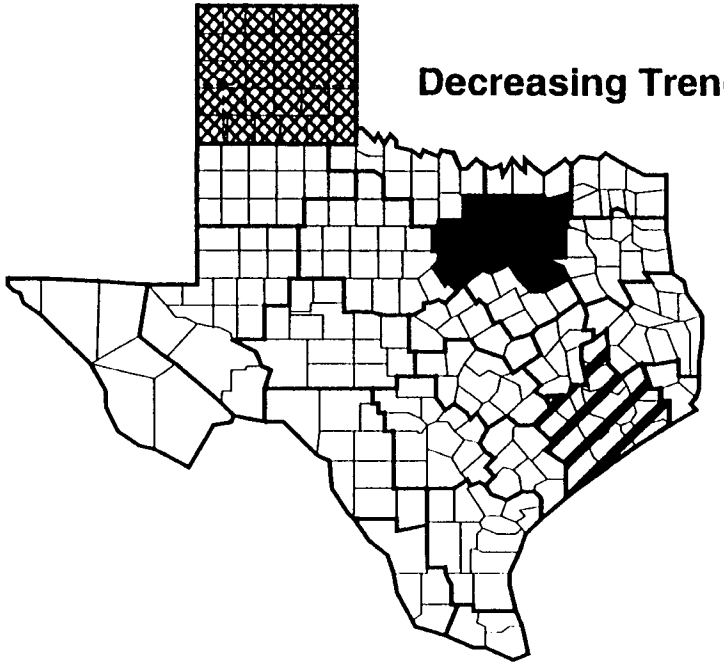
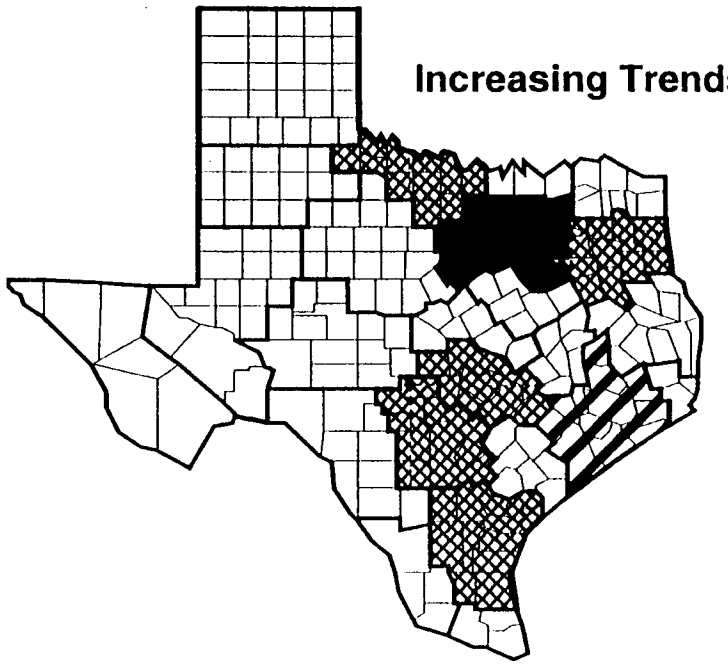
FIGURE 3

Decreasing and Increasing Trends in Cancer Mortality in Texas by Council of Governments, 1976-1989



Decreasing Trends

↓ Pancreas	Hispanic	female
↓ Bladder	Hispanic	male
↓ Stomach	Anglo	male
↓ Cervix	Anglo	female
↓ Gallbladder	Hispanic	male
↓ Stomach	Hispanic	male
↓ Cervix	Hispanic	female



Increasing Trends

↑ Lung	Anglo	female
↑ Lung	Anglo	female
↑ Lung	Black	female
↑ Lung	Anglo	female
↑ Lung	Black	female
↑ Lung	Black	male
↑ Large Intestine	Black	male

Source: Unpublished data, Cancer Registry Division, Texas Department of Health, prior trends from Riggan et al., 1983 (EPA/NCI)

2.3 Geographic Variation in Cancer Mortality Within Texas

Figures E-1 through E-6 (Appendix E) contain results of the standardized mortality ratio (SMR) analysis for 1980-1991. In relation to Texas as a whole, the southern tip of Texas is noteworthy for its deficit of cancer of the large intestine among both sexes in Hispanics and Anglos (Figure E-1). Cancer of the liver was noticeably greater than expected in the region including San Antonio/Bexar County with excesses among Hispanics and Anglos of both sexes (Figure E-2). No discernible geographic pattern was observed for the hematopoietic cancers (Figure E-5). Cancer of the lung and pleura (Figure E-6) was remarkable for an excess among black males and black females, Hispanic males and Anglo females within the region encompassing Corpus Christi (Nueces County).

Overall, as can be seen in Table E-1 (Appendix E), five areas in Texas experienced notably more excesses of various cancers. These included the Orange/Jefferson County area (COG 15), but not among Anglo males; the Victoria area (COG 17); the Corpus Christi area (COG 20), primarily in Hispanic males; the El Paso area (COG 8), especially among Anglo females; and the San Antonio area (COG 18). A pronounced deficit of various cancers was experienced in the Brownsville area (COG 21), primarily in Hispanics. Seven other regions of the state with significantly lower SMRs among multiple cancer sites were the El Paso area (COG 8), the Lubbock area (COG 2), the Texarkana area (COG 5), the Sherman-Denison area (COG 22), the Longview-Tyler area (COG 6), the Lufkin area (COG 14) and the Temple area (COG 23). However, it should be noted that these excesses and deficits do not imply a single cause as they occurred in a wide variety of cancers and sex/race/ethnic groups.

Using an SMR $\geq$ 110 or $\leq$ 91 as the cut-off criteria, the regions of Texas were re-evaluated to determine if conclusions regarding the relative excesses and deficits of various cancers would have altered substantially. Cancer excesses surfaced in COG 16 which contains the Houston/Harris County metropolitan area, especially in white males and females. However, this was the only Texas region for which a different conclusion would have been reached based on an SMR $\geq$ 110 or $\leq$ 91 vs. an SMR $\geq$ 120 or $\leq$ 83. So, with less strict criteria, six regions in Texas experienced excesses of different types of cancer (the five areas previously noted using the SMR cut-off of 120 plus the additional Houston/Harris County area). Four of the areas occurred on the Texas Gulf Coast. Tables E-2 and E-3 list the significant excesses and deficits by cancer type and sex/race/ethnic group for each COG using the higher (20%) and lower (10%) SMR cut-off, respectively.

3.0 SUMMARY OF STUDIES IN INDUSTRIAL SETTINGS

The cancer mortality experience presented in Section 2.0 was comprehensive in that it covered the entire state geographically and included all ages, race/ethnic groups, and both sexes. The time frame for the analyses focused primarily on the decade of the 1980s. We turn now to the critical review of the literature on studies conducted in industrial settings. These populations were composed primarily of white males who worked in refining or chemical manufacturing plants along the upper Gulf Coast area of Texas.

3.1 Historical Cohort Mortality Studies

Forty-three historical cohort mortality studies were conducted among Texas industrial workers. Some were overall mortality studies in the entire plant population, and some were restricted to workers in more specific job categories. Two industry-wide studies among painters and vinyl chloride workers were also included although the populations were not limited to Texas (Matanoski, 1986; Wong et al., 1991). Many of the cohort studies included overlapping populations or the same population with extended follow-up. Characteristics of these 43 studies are displayed in Table 5 where they are listed alphabetically by company name. To summarize SMRs across all the historical cohort mortality studies conducted on refinery and chemical manufacturing workers, one study from each refinery or chemical manufacturing company was selected to represent that company. The one selected contained the most inclusive population and the most recent mortality update for that company (i.e., not limited to a small subset of workers). These criteria yielded 11 independent populations from 10 companies. The quantitative summaries of the standardized mortality ratios (SMRs) from these studies by cancer type and type of plant are presented and described in Section 3.2 (and are noted by "*" in Table 5).

The cohort studies cover a wide range of possible exposures--petrochemicals, petroleum products, dioxane, epichlorohydrin, asbestos, among others. Personal exposure measurements were absent; area industrial hygiene measurements were rare, and usually taken many years after the potentially most relevant exposures. Exposures based on the largest and most comprehensive cohorts may have been diluted, since they included all job categories, many of which had limited potential for exposure.

The follow-up period for the studies ranged from 5 years (Matanoski et al., 1986) to 50 years (Olsen et al., in press). The cohort sizes ranged dramatically from only 99 workers with specific jobs related to ethylene dibromide exposures (Ott et al., 1980a) to 23,180 for Dow Chemical Company's 50 year overall cohort mortality study (Olsen et al., in press). Only in the largest studies were specific cancer risks examined by the original authors by follow-up periods and duration of exposure.

The percent with unknown vital status ranged from none (Buffler et al., 1979) to 6.4% (Wen et al., 1983). The percent of deaths where the death certificate was not located ranged from none (Tsai et al., 1983; Ross and Enterline, 1982; Enterline et al., 1990) to 14.3% (Ott et

TABLE 5

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Selected Characteristics of Historical Cohort Mortality Studies Conducted in Industrial Populations in Texas

Author, Year	Company	Years	Followup	Comparison	ICD Rev	Minimum Exposure	Cohort Number	Person-Years	Vital Status Unknown Percentage	No Death Certificate Percentage	Comments and Location of plant(s)
Bond et al., 1985a	Dow Chemical USA	1940-1977	1940-1977	US WM	8	ever	1,666	38,515	1.9	0.9	Based on 5% sample of cohort (Freeport)
Bond et al., 1985b	Dow Chemical USA	1940-1980	1940-1980	US WM TX WM 5 - County	8	≥ 1 yr	19,608	407,094	2.7	3.6	Complete cohort of Bond et al., 1985a (Freeport)
*Olsen et al., in press	Dow Chemical Co.	1940-1989	1940-1989	US Males TX 5 - County	8	≥ 1 yr	23,180	580,000	0.9	1.0	Female data also presented separately in paper (Freeport)
Buffler et al., 1978	Dow Chemical USA	1954-1975	1954-1975	TX WM	8	> 1 mo	165	1,720	-	-	Dioxane workers (Freeport)
Buffler et al., 1979	Dow Chemical Co.	1948-1975	1948-1975	TX WM	8	≥ 2 consec. mos	464	-	0.0	-	Vinyl chloride monomer workers (Freeport)
Ott et al., 1980a	Dow Chemical USA	1942-1969	1942-1975	US WM	-	ever	99	-	1.0	14.3	Ethylene dibromide exposed workers (Freeport)
Ott et al., 1980b	Dow Chemical USA	1937-1970	1940-1975	US WM	8	≥ 1 yr	2,904	-	3.0	1.7	Styrene-based products - only 10% were Texas workers (Freeport)
Bond et al., 1992	Dow Chemical Co.	1937-1970	1940-1986	US WM	8	≥ 1 yr	2,904	89,925	0.4	-	Update of Ott et al., 1980b (Freeport)
Olsen et al., 1994	Dow Chemical Co.	1957-1986	1957-1989	US M	8	≥ 1 mo	1,064	12,574	-	-	Epichlorohydrin and allyl chloride workers (Freeport)
*Pifer, 1992	Eastman Chemical Co.	1974	1974-1991	TX WM Rochester Kodak	-	-	1,672	-	-	-	Fixed cohort (1974) (Longview)
*Sweeney et al., 1986	Ethyl Corp.	1952-1977	1952-1977	US M	at time of death	ever	2,510	40,981	1.0	1.4	Conducted by NIOSH/OSHA (Pasadena)

Author, Year	Company	Years	Followup	Comparison	ICD Rev	Minimum Exposure	Cohort Number	Person-Years	Vital Status Unknown Percentage	No Death Certificate Percentage	Comments and Location of plant(s)
Hanis et al., 1985a	Exxon Corp.	1970-1977	1970-1977	US	8	≥ 1 mo	7,322	46,193	1.3	0.8	Also included retirees alive as of 1970, Texas - 1 of 3 plants (Baytown)
Hanis et al., 1985b	Exxon Corp.	1970-1977	1970-1977	Internal comparision	8	≥ 1 mo	7,322	46,193	1.3	0.8	Same as Hanis et al., 1985a but using internal comparison (Baytown)
*Shallenberger et al., 1992	Exxon Co. USA	1970-1982	1970-1982	TX	8	≥ 1 mo	8,722	80,684	1.7	0.1	Update of Hanis et al., 1985 a & busing Texas as comparison (Baytown)
*Wen et al., 1983	Gulf Oil Corp.	1937-1978	1937-1978	US M	8	ever	15,095	372,505	6.4	6.5	Mortality of hourly and salaried workers (Port Arthur)
Wen et al., 1984	Gulf Oil Corp.	1937-1978	1937-1978	US WM	8	ever	12,526	313,188	5.8	6.5	Sequel of Wen et al., 1983 by employment status (Port Arthur)
Wen et al., 1986	Chevron Corp. (formerly Gulf)	1937-1978	1937-1978	US WM	8	ever	12,527	313,272	5.8	6.3	Sequel of Wen et al., 1983 by WWII employment (Port Arthur)
Tsai et al., 1983	Gulf Oil Corp.	1952-1978	1952-1978	US M	8	ever	454	5,900	0.7	0.0	Benzene areas of refinery (Port Arthur)
Wen et al., 1985	Gulf Oil Corp.	1935-1978	1935-1978	US M	8	ever	1,008	21,795	2.6	2.0	Lubricating/dewaxing workers (Port Arthur)
*Morgan and Wong, 1984	Mobil Oil Corp.	1945-1978	1946-1978	US M	8	≥ 1 yr	5,696	116,274	3.0	2.0	Unpublished Environmental Health Associates report (Beaumont)
DeFonso, 1977	Rohm & Haas Co.	1948-1972	1948-1976	US M	8	ever	1,775	16,711	-	-	(Deer Park Plant)
Defonso and Maher, 1981	Rohm & Haas Co.	1948-1977	1948-1978	US WM	7,8	ever	1,849		3.9	0.8	Update of DeFonso, 1977 (Deer Park)

Author, Year	Company	Years	Followup	Comparison	ICD Rev	Minimum Exposure	Cohort Number	Person-Years	Vital Status Unknown Percentage	No Death Certificate Percentage	Comments and Location of plant(s)
'Haring, 1983	Rohm & Haas Co.	1948-1977	1948-1978	US WM	7	ever	1,845	-	4.0		NIOSH reanalysis of DeFonso and Maher, 1981 (Deer Park)
'Marsh et al., 1991	Shell Oil Co.	1948-1972	1948-1983	Harris County M	8	≥ 3 mos	6,123	-	2.0	4.6	3,593 refinery workers & 2,530 manufacturing workers analyzed separately (Deer Park)
Ross and Eterline, 1982	Shell Oil Co.	1948-1965	1948-1975	TX WM		≥ 6 mos	305	6,248	3.9	0.0	Lubricating/dewaxing workers (Deer Park)
Enterline et al., 1990	Shell Oil Co.	1948-1965	1960-1983	Harris County	8	≥ 3 mos	470	10,756	0.2	0.0	Epichlorohydrin workers (Deer Park)
'Divine et al., 1985	Texaco Inc.	1947-1977	1947-1977	US WM	7	≥ 5 yrs	19,077	358,029	2.3	3.8	Includes all Texaco plants, not just Texas
Divine and Barron, 1986	Texaco Inc.	1947-1977	1947-1977	US WM	7	≥ 5 yrs	18,519	-	2.3	3.8	Same as Divine, et al., 1985 by job categories
Divine and Barron, 1987	Texaco Inc.	1946-1980	1946-1980	US WM	8	≥ 6 mos	11,098	220,414	2.2	3.4	Producing and pipeline workers (not just Texas)
Morgan et al., 1981	Texaco Inc.	1955-1977	1955-1977	US M	7	≥ 5 yrs	767	13,969	<5.0	8.7	Ethylene oxide (Port Neches)
Downs et al., 1987	Texaco Inc.	1943-1979	1943-1979	US WM 7 - County	8	≥ 6 mos	2,586	64,800	2.8	4.0	Butadiene plant (Port Neches)
Divine, 1990	Texaco Inc.	1943-1979	1943-1985	US WM	8	≥ 6 mos	2,582	74,219	1.9	6.0	Update of Downs et al., 1987 (Port Neches)
Meinhardt et al., 1982	4 companies including Texaco	1943-1976	1943-1976	US WM	7	≥ 6 mos	2,756	53,929	3.2	2.5	Follow-up varies for two styrene-butadiene plants (Port Neches)
Lemen et al., 1990	4 companies including Texaco	1943-1976	1943-1982	US WM	7	≥ 6 mos	2,756	69,655	3.2	2.7	Extension of Meinhardt et al., 1982 - both by NIOSH (Port Neches)

Author, Year	Company	Years	Followup	Comparison	ICD Rev	Minimum Exposure	Cohort Number	Person-Years	Vital Status Unknown Percentage	No Death Certificate Percentage	Comments and Location of plant(s)
Waxweiller et al., 1983	Union Carbide Corp.	1941-1977	1941-1977	US M	7	ever	6,051	132,341	3.7	2.7	NIOSH analysis of hourly only (Texas City)
Austin and Schnatter, 1983a	Union Carbide Corp.	1941-1977	1941-1977	US WM	7	ever	6,588	137,745	2.8	2.1	Independent analysis of Waxweiller et al., 1983 by Union Carbide (Texas City)
*Teta et al., 1991	Union Carbide Chem.	1941-1983	1950-1983	US, TX M	7	ever	7,849	-	1.0	1.0	Update of Austin and Schnatter, 1983 (Texas City)
Lewisohn and Ott, 1991	Union Carbide Chem.	1947-1983	1950-1983	Internal Comparison	-	≥ 1 mo	204	-	1.0	-	Ethyleneamine workers (Texas City)
Teta et al., 1992	Union Carbide Chem.	1941-1978	1950-1983	US M	-	≥ 1 mo	493	-	1.0		Ethanol and isopropanol workers (Texas City)
Matanoski et al., 1986	Painters Union	1975-1979	1975-1979	US WM	8	≥ 1 yr	57,175	257,222	2.2	5.4	Included members from Texas and 3 other states
Wong et al., 1991	17 Companies	1942-1972	1942-1982	US WM	7	≥ 1 yr	9,370	-	7.9	6.0	This was industry-wide study - no separate analysis for Texas
Carlo et al., 1993	Tire Plant	1962-1989	1962-1989	US M	ICD - Time of death	≥ 1 yr	2,306	43,608	1.0	5.6	Tire plant in Tyler, Texas
Giacco, 1985	Asbestos Plant	1954-1972	1954-1981	US WM	8	ever	641	-	5.0	6.0	Asbestos plant in Tyler, Texas

* Included in Summary SMR Table 6

NOTE: WM = white male
M = male
TX = Texas

al., 1980a), but was generally low and quite acceptable. The comparison population selected to represent an unexposed population was generally U.S. white males. Texas, local county, or an internal comparison population were less often used.

Exclusive of the overall cohort mortality studies summarized in Section 3.2, results from the more specific exposure cohorts will be summarized here. Buffler et al. (1978) compared the mortality of 165 male employees at Dow Chemical U.S.A. Freeport who were ever exposed to 1,4-dioxane from 1954-1975 to that of Texas white males. Manufacturing and processing workers experienced 3 observed cancer deaths compared to 1.7 expected. Problems of small cohort size, small number of deaths, short follow-up time (only 41% of the cohort could meet the 10-year latency criteria), other potential exposures, and short duration of exposures made the results inconclusive. Buffler et al. (1979) compared the mortality among 464 white males employed at least two consecutive months in Dow Chemical Company Freeport vinyl chloride monomer production plant from 1948-1975 to Texas white male mortality. There were 5 observed versus 1.73 expected lung cancer deaths (SMR=289, $p<0.05$), and the SMR increased with duration and level of exposure based on indices developed during the first five years since initial exposure. The smoking analysis was incomplete as 28% of the cohort had no smoking history available. However, an analysis including all unknowns as smokers suggested the excess of lung cancer in this cohort was not attributable solely to smoking. Due to the small number of deaths, this study may only suggest an increase in the risk of lung cancer. Ott et al. (1980a) compared 161 males (99 in Texas) ever employed at two Dow Chemical U.S.A. ethylene dibromide (EDB) facilities during 1942-1969 (Texas) and 1925-1976 (Michigan) to the mortality of U.S. white males. Two cancer deaths occurred in the Texas plant versus 3.6 expected and 5 occurred in the Michigan plant versus 2.2 expected. These data were limited by extremely small numbers, exclusion of terminees prior to 1940, incomplete death certificate retrieval, and likely concomitant occupational exposures.

Two studies of lubricating/dewaxing refinery workers were conducted in the Shell (Ross and Enterline, 1982) and Gulf (Wen et al., 1985) populations. In an unpublished report to the National Institute for Occupational Safety and Health (NIOSH), Dr. Enterline from the University of Pittsburgh, compared the mortality through 1975 of 305 men who worked at least six months during 1948-1965 at Shell Oil Company's Deer Park Dewaxing Unit to that expected based on Texas white males (Ross and Enterline, 1982). Based on only two prostate cancer deaths, there was a significantly elevated SMR for genital cancer (SMR=952, $p<0.05$). The author noted the low power of the study and concluded that prostate cancer deaths were suggestive of an occupational hazard and recommended continued follow-up. Wen et al. (1985) focused on 1,008 Gulf Oil Corporation males who were ever employed in lubricating oils/dewaxing process at the Port Arthur refinery from 1935-1978. A slight, but nonsignificant elevation was noted for prostate cancer (SMR=182, 95% CI=78-358), but was not associated with any single exposure. When these results were grouped with the Ross and Enterline (1982) study of Shell Oil Company workers and another earlier study in dewaxing plants (Alderson and Rattan, 1980), the SMR for prostate cancer was 193 ($p=0.08$).

Two studies were conducted among epichlorohydrin (ECH) exposed workers at Shell Deer Park and Dow Freeport, the only two current producers of epichlorohydrin in the U.S. Enterline et al. (1990) at the University of Pittsburgh studied 863 male workers (470 in Texas) with at least three months in ECH departments during 1948-1965 (except maintenance workers at Shell Deer Park, Texas) and at least six months (including maintenance) in Norco, Louisiana and followed for mortality from 1948-1983. There was no excess of total cancer based on 17 observed deaths in Deer Park (SMR=92), although the SMR increased with greater latency and probable intensity of exposure. Because of the small number of workers involved, most of the results in cancer-specific categories were based on only one or two deaths. Olsen et al. (1994) compared the mortality of 1,064 male employees (through 1989) of Dow Chemical Company Freeport during 1957-1986 with at least one year of employment and at least one month in an epichlorohydrin-exposed job to both the U.S. males and an internal Dow Freeport comparison group. There was a significant deficit in total cancer mortality (3-year latency SMR=50, 95% CI=24-92) based on 10 observed cancer deaths. The postulated excess of lung cancer among ECH workers was not supported by either the Enterline et al. (1990) study (respiratory cancer SMR=97.5, no CI given based on 8 deaths) or the Olsen et al. (1994) study (SMR=13, 95% CI=1-75) based on only one death.

Morgan et al. (1981) examined mortality patterns of 767 males employed at least five years at the Texaco Inc. Port Neches plant during 1955-1977, who had potential exposure to ethylene oxide according to industrial hygiene review of job descriptions. The authors were particularly interested in leukemia deaths, but none occurred. There was no overall excess in total cancer, and the numbers in this study were too small to allow for subanalyses of specific types of cancer deaths by latency or duration of exposure. A recent assessment of the epidemiologic evidence on the carcinogenicity of ethylene oxide also indicated no excess of total cancer (summary SMR=94, 95% CI=88-101). The summary SMR for leukemia was 112 (95% CI=79-156) with no observable overall trend for intensity and frequency of exposure; however, the summary SMR for leukemia among workers with the longest latency (i.e., 20 or more years since first exposure) was statistically significant (SMR=2.1, p=0.02) (Shore et al., 1993).

Gulf Oil Corporation (Tsai et al., 1983) conducted a historical cohort mortality study among 454 employees ever employed in benzene, cumene, aromatic distillate hydrogenation, or ethylene units from 1952-1978. Fifty-three percent of the employees had four or fewer years of exposure and the authors documented low exposures. No leukemias were seen, and the numbers were too small to determine or discuss any other possible excesses.

Two small studies were conducted on more specific exposed Union Carbide Chemical cohorts--ethylene amine exposed workers (Lewinsohn and Ott, 1991) and ethanol and isopropanol production workers (Teta et al., 1992). The evidence in both cases was limited due to small numbers. In the Lewisohn and Ott (1991) study, cancer mortality was only a small part of the study (only 2 cancer deaths were observed). Where the number of cancer-specific causes of death were greater than expected for Texas workers in the Teta et al. (1992) study, they were based on only one observed death.

Six studies pertained to workers at styrene, butadiene, or styrene-butadiene plants. A series of two studies (Ott et al., 1980b; Bond et al., 1992) examined mortality among 2,904 males employed at least one year during 1937-1970 in Dow Chemical U.S.A. production or research of styrene-based products. Only 10% of the employees in the cohort worked in Texas. The second study updated the earlier one by extending follow-up for 11 years through 1986. An elevated, but nonsignificant, excess occurred for lymphohematopoietic cancer (SMR=144, 95% CI=95-208). Analysis by work area showed most of the excess concentrated in polymerization, coloring, and extrusion areas. There were no trends of increasing risk with increasing duration or latency. There were no separate analyses for the Texas workers (n=296). These two studies incorporated one of the most elaborate attempts to estimate styrene exposure (multiple agent, multiple route approach) of all the styrene-related studies. Two studies examined the mortality of 2,586 male permanent workers at Texaco Inc.'s Port Neches butadiene plant who were employed at least six months during 1943-1979 (Downs et al., 1987; Divine, 1990). The second of these studies updated the mortality of the Downs et al. (1987) study by six years through 1985. The SMR for lymphosarcoma and reticulosarcoma was statistically elevated (SMR=229, 95% CI=104-435), but did not increase consistently for longer work durations or latency periods, making a causal association less compelling. NIOSH conducted two studies in response to a reported cluster of two leukemia deaths at two styrene-butadiene plants in Port Neches, Texas variously owned by BF Goodrich, Firestone, U.S. Rubber, and Texaco Inc. (Meinhardt et al., 1982; Lemen et al., 1990). This cohort was different from the butadiene cohort reported by Downs et al. (1987) and Divine (1990). The cohort consisted of 1,662 white males employed at least six months at Plant A during 1943-1976 and 1,094 white males similarly employed at Plant B during 1950-1976. The second analysis extended the follow-up from 1976 to 1981 for Plant A and to 1982 for Plant B. SMRs were elevated for lymphosarcoma/reticulosarcoma and leukemia (no confidence intervals given). The authors of the second study emphasized the difficulty in attributing health risks to specific chemicals and the importance of continuing to study workers in a mixed chemical low-level exposure environment.

The remaining four studies were industry-wide studies or studies focusing on workers not employed in the petrochemical industry. The industry-wide studies (not limited to Texas) suggested elevated total cancers, stomach, and lung cancer among painters (Matanoski, 1986) and an excess of brain and liver/biliary cancers among vinyl chloride workers (Wong et al., 1991). Carlo et al. (1993) studied 1,876 white and 430 non-white males employed at least one year during 1962-1989 at a tire manufacturing plant in Tyler, Texas. There were no significant SMRs, yet the population was small, young, and the latency periods were short. Giacco (1985) confirmed asbestos as a risk factor for lung cancer in an historical cohort study of 641 white men employed at a Tyler, Texas asbestos plant between 1954-1972.

In summary, the gain in specificity of exposure information obtained by limiting these cohort studies to subgroups of workers was offset by the loss in power to be able to reliably estimate cancer risk associated with particular exposures.

3.2 Summary SMRs by Type of Plant and Cancer Type for Petrochemical Cohort Mortality Studies in Texas

With the numerous studies included in this review, a systematic quantitative summary of study results (Table 6) allows an overview of the overall cancer results not easily recognized by individual review. Although others may refer to this summarization as a meta-analysis, the authors are reluctant to use this term since the studies were limited to Texas, and therefore did not include all available evidence about the exposure and cancer outcomes, a necessary assumption for a meta-analysis. Further, the combining of studies with heterogeneous exposure measures of varying quality, different cohort definitions, standard populations used for comparison, follow-up duration, and calendar time makes interpretation of the summary results problematic. Yet, a summary across the studies and consistency of the results across individual studies would yield important information for the initiation of future studies and further scrutiny of possible exposures.

The following summary is limited to historical cohort mortality studies conducted in petroleum refinery and chemical manufacturing working populations in Texas. Thirty-nine studies met these criteria (the first 39 studies listed in Table 5; the last four studies were either industry-wide (Matanoski et al., 1986; Wong et al., 1991) or not in petrochemical populations (Carlo et al., 1993; Giacco, 1985)), yet many were overlapping studies conducted on the same population or a subset of the population. Therefore, a further restriction required independence of the study populations, and when studies overlapped, the largest or most recent one was selected as indicated below for each company.

(1) Three sequentially updated historical cohort mortality studies have been published on workers ever employed by Dow Chemical Company populations (Bond et al., 1985a, Bond et al., 1985b; Olsen et al., in press). The most recent study (reference #8 in Table 6) was selected to represent Dow Chemical Company in the summary SMR analysis and included 50 years of follow-up (Olsen et al., in press).

(2) An unpublished Eastman Chemical Company report (Pifer, 1992), describing the mortality experience through 1991 of a fixed cohort of 1,672 men who were ever employed at Texas Eastman Company during 1974, was included in the summary SMR analysis (reference #7 in Table 6).

(3) The Oil, Chemical and Atomic Workers (OCAW) and Ethyl Corporation requested that NIOSH and OSHA conduct a cohort study on 2,510 male employees who were ever employed at the plant during 1952-1977 (Sweeney et al., 1986). This study represented the Ethyl Corporation in the summary SMR analysis (reference #5 in Table 6).

(4) Exxon Company USA published three overall cohort mortality studies (Hanis et al., 1985a, Hanis et al., 1985b; Shallenberger et al., 1992) on full-time regular employees and retirees alive as of 1/1/70 who worked at least one month during 1970-1977 at one of

TABLE 6

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Summary SMRs by Type of Plant and Cancer Type for 11 Non-Overlapping Petrochemical Plants in Texas

Cancer Type	Refinery				Manufacturing				Mixed Type				Total		
	O	E	SMR*	Ref†	O	E	SMR*	Ref†	O	E	SMR*	Ref†	O	E	SMR
All cancer sites#	839	878.0	96	(1)	23	32.0	72	(4)	767	1019.4	75	(9)			
	338	351.8	96	(2)	38	37.0	103	(5)	308	354.0	87	(10)			
	182	227.5	80	(3)	67	78.8	85	(3)							
					318	334.6	95	(6)							
					48	79.0	61	(7)							
					1358	1340.5	101	(8)							
Summary SMR	1359	1457.3	93		1852	1901.9	97		1075	1373.4	78		4286	4732.6	91
95% CI	87 - 99				91 - 103				73 - 83				86 - 96		
Buccal Cavity/Pharynx	20	29.5	68	(1)	0	1.1	0	(4)	-	-	-	(9)			
	3	11.2	27	(2)	-	-	-	(5)	-	-	-	(10)			
	4	8.2	49	(3)	3	2.8	108	(3)							
					-	-	-	(6)							
					0	2.1	0	(7)							
					23	39.0	59	(8)							
Summary SMR	27	48.9	55		26	45.0	58		-	-	-		53	93.9	56
95% CI	36 - 80				38 - 85								42 - 74		

*As taken directly from the reference
†See references at end of Table
#Includes all cancers, not just selected cancers represented in this table.
O = Observed number of deaths
E = Expected number of deaths

TABLE 6 Con't

Summary SMRs by Type of Plant and Cancer Type for 11 Non-Overlapping Petrochemical Plants in Texas

	Refinery				Manufacturing				Mixed Type				Total		
Cancer Type	O	E	SMR	Ref[1]	O	E	SMR	Ref[1]	O	E	SMR	Ref[1]	O	E	SMR
All Digestive	231	283.2	82	(1)	4	8.0	50	(4)	215	306.8	70	(9)			
	84	111.1	76	(2)	9	7.4	122	(5)	61[a]	67.9	90	(10)			
	40	54.1	74	(3)	10	17.2	58	(3)							
					85	88.3	96	(6)							
					16	17.4	92	(7)							
					289	353.1	82	(8)							
Summary SMR	355	448.4	79		413	491.4	84		276	374.7	74		1044	1314.5	79
95% CI		71 - 88				76 - 93				66 - 83				74 - 84	
Esophagus	12	27.0	44	(1)	-	-	-	(4)	-	-	-	(9)			
	8	10.7	75	(2)	-	-	-	(5)	9	7.2	125	(10)			
	3	5.9	51	(3)	1	2	50	(3)							
					-	-	-	(6)							
					-	-	-	(7)							
					25	31.9	78	(8)							
Summary SMR	23	43.6	53		26	33.9	77		9	7.2	125		58	84.7	68
95% CI		34 - 80				50 - 113				57 - 238				52 - 89	

[1]See references at end of Table
[a] All digestive except rectum, liver, biliary
O = Observed number of deaths
E = Expected number of deaths

TABLE 6 Con't

Summary SMRs by Type of Plant and Cancer Type for 11 Non-Overlapping Petrochemical Plants in Texas

Cancer Type	Refinery				Manufacturing				Mixed Type				Total		
	O	E	SMR	Ref†	O	E	SMR	Ref†	O	E	SMR	Ref†	O	E	SMR
Stomach	68	69.8	97	(1)	-	-	-	(4)	45	63.9	70	(9)			
	24	26.3	91	(2)	-	-	-	(5)	12	12.9	93	(10)			
	8	9.4	85	(3)	1	2.6	38	(3)							
					-	-	-	(6)							
					2	2.4	82	(7)							
					34	59.4	57	(8)							
Summary SMR	100	105.5	95		37	64.4	57		57	76.8	74		194	246.7	79
95% CI		78 - 116				40 - 79				56 - 97				68 - 91	
Colon and Rectum	84	108.8	77	(1)	-	-	-	(4)	64*	94.3	68	(9)			
	26	43.3	60	(2)	5	3.7	134	(5)	23*	28.0	82	(10)			
	17	19.7	86	(3)	4	5.3	75	(3)							
					29*	27.0	107	(6)							
					6	7.2	83	(7)							
					124	155.6	80	(8)							
Summary SMR	127	171.8	74		168	198.8	85		87	122.3	71		382	492.9	78
95% CI		62 - 88				73 - 99				57 - 88				70 - 86	

†See references at end of Table
* Includes colon only
O = Observed number of deaths
E = Expected number of deaths

TABLE 6 Con't

Summary SMRs by Type of Plant and Cancer Type for 11 Non-Overlapping Petrochemical Plants in Texas

Cancer Type	Refinery				Manufacturing				Mixed Type				Total		
	O	E	SMR	Ref†	O	E	SMR	Ref†	O	E	SMR	Ref†	O	E	SMR
Liver and Biliary	8	22.6	35	(1)	-	-	-	(4)	-	-	-	(9)			
	2	8.6	23	(2)	-	-	-	(5)	-	-	-	(10)			
	6	5.3	114	(3)	-	-	-	(3)							
					9	6.0	150	(6)							
					1	1.3	77	(7)							
					22	27.8	79	(8)							
Summary SMR	16	36.5	44		32	35.1	91		-	-	-		48	71.6	67
95% CI		25 - 71				62 - 129								49 - 89	
Pancreas	53	48.5	109	(1)	-	-	-	(4)	62	57.7	107	(9)			
	23	19.8	116	(2)	-	-	-	(5)	17	19.8	86	(10)			
	5	11.9	42	(3)	4	3.7	108	(3)							
					19	17.7	107	(6)							
					5	3.9	129	(7)							
					74	69.0	107	(8)							
Summary SMR	81	80.2	101		102	94.3	108		79	77.5	102		262	252	104
95% CI		81 - 126				89 - 132				81 - 126				92 - 118	

†See references at end of Table
O = Observed number of deaths
E = Expected number of deaths

TABLE 6 Con't

Summary SMRs by Type of Plant and Cancer Type for 11 Non-Overlapping Petrochemical Plants in Texas

	Refinery				Manufacturing				Mixed Type				Total		
Cancer Type	O	E	SMR	Ref†	O	E	SMR	Ref†	O	E	SMR	Ref†	O	E	SMR
Larynx	-	-	-	(1)	-	-	-	(4)	-	-	-	(9)			
	3	5.5	54	(2)	2	0.6	364	(5)	-	-	-	(10)			
	-	-	-	(3)	-	-	-	(3)							
					-	-	-	(6)							
					-	-	-	(7)							
					9	18.7	48	(8)							
Summary SMR	3	5.5	54		11	19.3	57		-	-	-		14	24.8	56
95% CI	11 - 158				28 - 102								31 - 94		
Lung	239	241.8	99	(1)	9*	11.2	80	(4)	182	306.0	59	(9)			
	100	99.3	101	(2)	14	12.5	112	(5)	98	128.9	76	(10)			
	66*	94.3	70	(3)	25*	33.8	74	(3)							
					114*	122.3	93	(6)							
					12*	32.1	37	(7)							
					518	455.5	114	(8)							
Summary SMR	405	435.4	93		692	667.4	104		280	434.9	64		1377	1537.7	90
95% CI	84 - 103				96 - 112				57 - 72				85 - 95		

†See references at end of Table
*Total respiratory
O = Observed number of deaths
E = Expected number of deaths

TABLE 6 Con't

Summary SMRs by Type of Plant and Cancer Type for 11 Non-Overlapping Petrochemical Plants in Texas

	Refinery				Manufacturing				Mixed Type				Total		
Cancer Type	O	E	SMR	Ref†	O	E	SMR	Ref†	O	E	SMR	Ref†	O	E	SMR
Prostate	78	72.3	108	(1)	-	-	-	(4)	62	73.1	85	(9)			
	36	32.1	112	(2)	-	-	-	(5)	-	-	-	(10)			
	14	13.1	107	(3)	4	2.5	159	(3)							
					-	-	-	(6)							
					-	-	-	(7)							
					65	90.3	72	(8)							
Summary SMR	128	117.5	109		69	92.8	74		62	73.1	85		259	283.4	91
95% CI		91 - 130				58 - 94				66 - 110				80 - 103	
Bladder	13	28.0	46	-	-	-	-	(4)	19	33.9	56	(9)			
	10	11.5	87	(2)	-	-	-	(5)	-	-	-	(10)			
	3	4.8	62	(3)	-	-	-	(3)							
					6	7.2	83	(6)							
					-	-	-	(7)							
					29	35.9	81	(8)							
Summary SMR	26	44.3	59		35	43.1	81		19	33.9	56		80	121.3	66
95% CI		39 - 87				56 - 113				34 - 87				53 - 83	

†See references at end of Table
O = Observed number of deaths
E = Expected number of deaths

TABLE 6 Con't

Summary SMRs by Type of Plant and Cancer Type for 11 Non-Overlapping Petrochemical Plants in Texas

Cancer Type	Refinery				Manufacturing				Mixed Type				Total		
	O	E	SMR[1]	Ref[1]	O	E	SMR[1]	Ref[1]	O	E	SMR[1]	Ref[1]	O	E	SMR[1]
Kidney	22	19.7	112	(1)	-	-	-	(4)	24	25.1	96	(9)			
	6	7.8	77	(2)	-	-	-	(5)	8	8.2	97	(10)			
	2	5.1	39	(3)	3	1.9	158	(3)							
					6	8.3	72	(6)							
					-	-	-	(7)							
					41	33.4	123	(8)							
Summary SMR	30	32.6	92		50	43.6	115		32	33.3	96		112	109.5	102
95% CI		62 - 132				85 - 152				66 - 136				84 - 125	
Skin	16	13.1	122	(1)	-	-	-	(4)	14	16.7	84	(9)			
	7	4.9	143	(2)	-	-	-	(5)	5	6.8	74	(10)			
	4	3.8	105	(3)	2	2.1	94	(3)							
					9	5.1	176	(6)							
					-	-	-	(7)							
					33	26.8	123	(8)							
Summary SMR	27	21.8	124		44	34.0	129		19	23.5	81		90	79.3	113
95% CI		82 - 181				94 - 173				49 - 126				91 - 140	

[1]See references at end of Table
O = Observed number of deaths
E = Expected number of deaths

TABLE 6 Con't

Summary SMRs by Type of Plant and Cancer Type for 11 Non-Overlapping Petrochemical Plants in Texas

Cancer Type	Refinery				Manufacturing				Mixed Type				Total		
	O	E	SMR	Ref†	O	E	SMR	Ref†	O	E	SMR	Ref†	O	E	SMR
Central Nervous System/Brain	30	30.4	99	(1)	-	-	-	(4)	31	28.0	111	(9)			
	8	8.0	100	(2)	4	1.9	213	(5)	12	7.7	156	(10)			
	6	6.5	92	(3)	2	3.1	65	(3)							
					17	11.1	153	(6)							
					2	2.5	81	(7)							
					45	40.0	113	(8)							
Summary SMR	44	44.9	98		70	58.6	119		43	35.7	120		157	139.2	113
95% CI		71 - 132				93 - 151				87 - 162				96 - 133	
All Lymphohematopoietic Cancers	80	78.7	102	(1)	3[a]	3.9	76	(4)	106	96.7	110	(9)			
	46	31.1	148	(2)	4[a]	4.7	85	(5)	32	31.1	103	(10)			
	26	20.5	127	(3)	9	8.1	111	(3)							
					30	32.7	92	(6)							
					4	7.4	54	(7)							
					124	130.0	95	(8)							
Summary SMR	152	130.3	117		174	186.8	93		138	127.8	108		464	444.9	104
95% CI		99 - 138				80 - 108				91 - 128				95 - 114	

†See references at end of Table
[a]Includes ICD(7) 200-205
O = Observed number of deaths
E = Expected number of deaths

TABLE 6 Con't

Summary SMRs by Type of Plant and Cancer Type for 11 Non-Overlapping Petrochemical Plants in Texas

Cancer Type	Refinery				Manufacturing				Mixed Type				Total		
	O	E	SMR*	Ref†	O	E	SMR*	Ref†	O	E	SMR*	Ref†	O	E	SMR*
Lymphosarcoma/ Reticulosarcoma	4	16.4	24	(1)	-	-	-	(4)	20	22.2	90	(9)			
	9	6.6	135	(2)	1	1.4	70	(5)	6	5.1	117	(10)			
	8	4.2	189	(3)	1	1.7	59	(3)							
					-	-	-	(6)							
					-	-	-	(7)							
					-	-	-	(8)							
Summary SMR	21	27.2	77		2	3.1	65		26	27.3	95		49	57.6	85
95% CI	48 - 118				8 - 235				62 - 140				63 - 113		
Hodgkin's Disease	16	11.0	145	(1)	-	-	-	(4)	13	12	108	(9)			
	2	3.7	54	(2)	-	-	-	(5)	-	-	-	(10)			
	3	2.2	135	(3)	-	-	-	(3)							
					-	-	-	(6)							
					-	-	-	(7)							
					-	-	-	(8)							
Summary SMR	21	16.9	124		-	-	-		13	12	108		34	28.9	118
95% CI	77 - 190								57 - 185				82 - 165		

†See references at end of Table
O = Observed number of deaths
E = Expected number of deaths

TABLE 6 Con't

Summary SMRs by Type of Plant and Cancer Type for 11 Non-Overlapping Petrochemical Plants in Texas

	Refinery				Manufacturing				Mixed Type				Total		
Cancer Type	O	E	SMR	Ref[f]	O	E	SMR	Ref[f]	O	E	SMR	Ref[f]	O	E	SMR
Leukemias	38	33.3	114	(1)	-	-	-	(4)	48	40.7	118	(9)			
	23	13.0	177	(2)	1	1.8	56	(5)	15	13.2	114	(10)			
	8	8.2	97	(3)	3	3.2	93	(3)							
					-	-	-	(6)							
					2	2.9	68	(7)							
					48	51.8	93	(8)							
Summary SMR	69	54.5	127		54	59.7	90		63	53.9	117		186	168.1	111
95% CI	100 - 162				68 - 118				91 - 151				96 - 128		
Other Lymphohematapoietic	20	17.4	115	(1)	-	-	-	(4)	25	21.8	115	(9)			
	12	7.4	161	(2)	2[b]	1.5	132	(5)	9	10.7	84	(10)			
	7	5.8	120	(3)	5	2.1	237	(3)							
					-	-	-	(6)							
					2[c]	4.5	45	(7)							
					-	-	-	(8)							
Summary SMR	39	30.6	127		9	8.1	111		34	32.5	105		82	71.2	115
95% CI	90 - 173				51 - 211				73 - 147				92 - 144		

[f]See references at end of Table
[b]Includes ICD(7) 202, 203, 205
[c]Includes other lymphoma
O = Observed number of deaths
E = Expected number of deaths

References for Summary SMRs

		Company	Comparison Population
(1)	Wen et al., 1983, Table 7, page 533	Gulf Oil Corporation	U.S.
(2)	Morgan and Wong, 1984, Table 16 (no page no.)	Mobil Oil Corporation	U.S.
(3)	Marsh et al., 1991, Table V, page 35	Shell Oil Company	Harris County
(4)	Haring, 1983, Table 3 (no page no.)	Rohm & Haas Company	U.S.
(5)	Sweeney et al., 1986, Table 3, page 25	Ethyl Corporation	U.S.
(6)	Teta et al., 1991, Table 1, page 46 (hourly & salary)	Union Carbide Chemical & Plastics Company, Inc.	U.S.
(7)	Pifer, 1992, Table 2, page 6	Eastman Chemical Company	Texas
(8)	Olsen et al., in press, Table III (no page no.)	Dow Chemical Company	U.S.
(9)	Divine et al., 1985, Table (no no.), page 446	Texaco Inc.	U.S.
(10)	Shallenberger et al., 1992, Table 2 (Baytown), page 349	Exxon Company, USA	U.S.

three refinery and chemical plants (Baytown, Texas; Bayway, New Jersey; and Baton Rouge, Louisiana). The most recent study (Shallenberger et al., 1992) updated the cohort by five years to 1982 (included 8,722 Baytown, Texas workers), and was used in the summary SMR analysis (reference # 10 in Table 6).

(5) Gulf Oil Corporation (later Chevron) published three historical cohort mortality studies among workers of different pay status (Wen et al., 1983), working status (Wen et al., 1984), and year of hire (Wen et al., 1986). The earliest study (Wen et al., 1983) on 15,095 male hourly and salaried workers who ever worked at the Texas refinery during 1937-1978, was the most inclusive and comparable to other plant studies, and was selected for inclusion in the summary SMR analysis (reference #1 in Table 6).

(6) An unpublished report by independent consultants (Morgan and Wong, 1984) described the mortality experience of 5,696 male and 443 female workers employed for at least one year at Mobil Oil Corporation's Beaumont refinery during 1945-1978. This report represented the mortality experience of Mobil Oil Corporation in the summary SMR analysis (reference #2 in Table 6).

(7) In a series of three unpublished cohort mortality studies, Rohm & Haas Company examined mortality among male employees at least 25 years of age employed at their Texas plant. DeFonso and Maher (1981) updated to 1978 the earlier mortality study (DeFonso, 1977) on 1,849 workers employed from 1948-1977. NIOSH reanalyzed this cohort (Haring, 1983), but included eight more deaths. This latter study was selected for inclusion in the summary analysis (reference #4 in Table 6).

(8,9) The University of Pittsburgh conducted the overall cohort mortality study for Shell Oil Company on 6,672 men (of which 3593 were male refinery only workers and 2530 were male chemical plant only workers) who worked at least three months for Shell Oil during 1948-1972 (Marsh et al., 1991). This report presents site-specific SMRs separately for refinery and chemical manufacturing, and therefore represents two independent populations in the summary SMR analysis (reference #3 in Table 6).

(10) The first in a series of three Texaco Inc. cohort studies compared the mortality of 19,077 white males employed at least five years during 1947-1977 at any Texaco Inc. refinery, petrochemical, or research facility (Divine et al., 1985). Nearly 60% of this cohort was employed at some time in Texas. This overall study was the one included in the summary SMR analysis (reference #9 in Table 6). A second Texaco analysis was conducted (Divine and Barron, 1986) to incorporate job histories as surrogates of exposure for the same cohort. A third study (Divine and Barron, 1987) was limited to 11,098 white males employed at least six months at a Texaco Inc. facility during 1946-1980 in production or pipeline jobs anywhere in the U.S. Approximately 32% were employed in Texas.

(11) Three overall cohort studies were conducted on Union Carbide Chemicals and Plastics Company, Inc. employees. The first two studies were conducted on the same population by NIOSH and Union Carbide (Waxweiler et al., 1983; Austin and Schnatter, 1983a). Teta et al. (1991) updated the Union Carbide analysis to 1983 by adding six years of observation and expanded the cohort to include nonwhites and all Texas City workers ever employed from 1941-1983. This latter study was selected for inclusion in the summary SMR analysis (reference #6 in Table 6).

Data were further limited to males due to insufficient numbers and often absent data for females. These populations were stratified by primary plant activity (refinery; chemical manufacturing; or mixed type, unable to differentiate) and cancer type. The chemical manufacturing category should be recognized as having very heterogeneous exposures, covering numerous chemicals. The refining category is more homogeneous, and includes chemicals and products usually produced from crude oil fractions and refinement. The designation of refinery versus mixed type was particularly problematic since all refineries also produced some petrochemicals. If, in a refinery, the published report indicated production of more complex chemicals (e.g., halogenated compounds), in addition to those typically produced in refineries, the plant population was designated as mixed. For each cancer type and company, the number of observed and expected deaths, and SMR is presented in Table 6. For each cancer type, a summary SMR was calculated for each of the three plant types and for all 11 plant populations together (if data were available). The summary SMRs were calculated by dividing the sum of the observed number of deaths across the individual studies by the sum of the expected number of deaths across each study. This method of calculating summary SMRs is intuitively appealing due to its comparability of calculation with the individual SMRs, its weighting by study size (observed and expected numbers of deaths), and its maintenance of the indirect adjustment used in each study (e.g., age, race, calendar time). This method has been used in other reviews (Wong and Raabe, 1989). However, this method assumes homogeneity of SMRs across strata (i.e., companies). If this assumption is not met, this method provides an overall estimate of risk with a narrower confidence interval than if heterogeneity had been taken into account (DerSimonian and Laird, 1986; Fleiss and Gross, 1991). The procedure utilized in this report, therefore, is a less restrictive one, whose use is intended for screening purposes and not for hypothesis testing. Ninety-five percent confidence intervals for the SMRs were calculated based on the Poisson distribution.

This analysis was descriptive in nature; SMR excesses and deficits of interest will be noted by cancer type with no minimum criteria set for magnitude. However, consistent with the geographic cancer mortality analyses presented in Section 2.0, SMRs ≥ 120 or ≤ 83 and ≥ 110 or ≤ 91 will be noted for the overall summary by plant type. To utilize these analyses to screen for potential excesses in specific cancers among petroleum refinery and chemical manufacturing workers in Texas, a statistically significant excess was not required for discussion purposes. Rather, the confidence intervals, in addition to the SMRs, are indicative of the statistical certainty (or lack of) of the SMR estimates. Significant deficits will also be noted.

All Cancers Combined (4,286 cases)

For refinery workers, mixed plant, and all workers, there was a significant deficit of total cancers. For manufacturing workers, the summary SMR was below 100, and only barely exceeded 100 in two of the six manufacturing populations. Based on the 4,286 total cancer deaths in these 11 populations, the overall summary SMR was 91 (95% CI=86-96).

Buccal Cavity/Pharynx (53 cases)

Even though based on small numbers, the summary SMRs for buccal cavity/pharynx was significantly low for refinery, manufacturing, and total workers (SMR=56, 95% CI=42-74) (there were no data for mixed type plants). Only one SMR from an individual study exceeded 100 (Shell Oil Company manufacturing, SMR=108), but was based on only 3 deaths.

All Digestive Cancers (1,044 cases)

There was a significant deficit of all digestive cancers among refinery, manufacturing, mixed plant workers, and all workers. Individual plant SMRs ranged from 50 to 122; the highest SMR based on 9 deaths (Ethyl Corporation) being the only one of the 11 populations exceeding 100.

Esophagus (58 cases)

For refinery workers, manufacturing workers, and all workers combined, all individual and summary SMRs were below 100 (all worker SMR=68, 95% CI=52-89). The only SMR above 100 was based on 9 esophageal deaths in the one mixed plant study with available data (SMR=125).

Stomach (194 cases)

All SMRs for stomach cancer were below 100, and significantly low for manufacturing, mixed type, and all workers (SMR=79, 95% CI=68-91).

Colon/Rectum (382 cases)

All summary SMRs were statistically significantly low for colon/rectum cancer, the largest category of digestive cancers. Only two of the eleven SMRs exceeded 100 (Ethyl Corporation and Union Carbide Chemicals & Plastics Company, Inc., both chemical manufacturing populations), but were based on only 5 and 29 deaths, respectively. Using broad classification of exposure methods without regard to individual more specific exposures, the excesses noted among polypropylene workers in the Exxon Biomedical Sciences, Inc. studies were not apparent in the overall cohort.

Liver and Biliary (48 cases)

The summary SMRs indicated a deficit of liver/biliary cancer and ranged from 44 in the refinery population to 91 in the manufacturing workers (with no information available on the mixed plant populations).

Pancreas (262 cases)

Of the SMRs from the nine studies with data for pancreatic cancer, seven exceeded 100. The individual SMRs ranged from 42 to 129. None of the summary SMRs was significant. However, all four of the manufacturing population SMRs exceeded 100, although low in magnitude. The overall summary SMR for pancreatic cancer was 104 (95% CI=92-118).

Larynx (14 cases)

Based on very sparse data, the summary SMRs for laryngeal cancer by plant type showed more than a 40% deficit of this type of cancer (SMR=56, 95% CI=31-94).

Lung (1,377 cases)

The overall summary lung cancer SMR was significantly low (SMR=90, 95% CI=85-95). More than a 10% excess was detected in the Ethyl Corporation and Dow Chemical Company populations causing the summary SMR for the manufacturing group to exceed 100 (SMR=104, 95% CI=96-112). In the Ethyl Corporation population, there was a latency effect for respiratory cancer, but no dose-response effect (highest SMR was among workers with less than 10 years employment). The cohort study in the Dow Chemical Company population, which found an elevated SMR for lung cancer, used the U.S. as the comparison. This elevation persisted when Texas was used as a comparison, but diminished when compared to the five-county region. However, there was no clear trend by latency or duration of employment by first job title. The lung cancer SMR among operations employees (SMR=125, 95% CI=113-137) was nearly twice as high as among administrators (SMR=82, 95% CI=66-100). A 1984 survey of smoking also indicated a two-fold difference in the prevalence of smoking (37.4% among male operators compared to 19.1% among male managers and administrators (Olsen et al., 1990a; 1991)).

Prostate (259 cases)

The overall prostate cancer SMR for the entire refinery and petrochemical industry workers was 9% lower than the general population (SMR=91, 95% CI=80-103). All SMRs exceeded 100 among refinery workers although the overall excess was quite small (summary SMR=109, 95% CI=91-130). The summary SMRs for the manufacturing and mixed type workers were quite low, but data were available from only three of the study populations.

Bladder (80 cases)

All individual SMRs for bladder cancer were below 100 (range=46-87) and produced a statistically significant deficit for the overall population (SMR=66, 95% CI=53-83).

Kidney (112 cases)

The summary SMRs were close to 100 for the refinery, and for the mixed plant populations. However, among the manufacturing workers (with data from three of the five populations), the summary SMR indicated a 15% increase in kidney cancer deaths (95% confidence interval=85-152). This was heavily weighted by the Dow Chemical Company study (SMR=123) which represented 41 of the 50 deaths in the manufacturing workers. The kidney cancer excess persisted when compared to three comparison groups in Dow Chemical Company workers (U.S., Texas, and five-county region), increased with greater than 15-year latency, but demonstrated an inconsistent pattern with duration of employment. An earlier Dow Chemical Company case-control study of kidney cancer (Bond et al., 1985c) implicated employment in the cell maintenance area of chlorine production with exposure to asbestos and caustic.

Skin (90 cases)

Among refinery workers, all SMRs for skin cancer (predominantly melanoma) exceeded 100 (summary SMR=124, 95% CI=82-181). Primarily heavily weighted by the large Dow Chemical Company population, and an excess of greater magnitude (but smaller numbers) in the Union Carbide Chemicals & Plastics Company, Inc. cohort, the summary SMR indicated a 29% increase in skin cancer deaths in manufacturing workers (SMR=129, 95% CI=94-173). No excess occurred among mixed type plant workers. Since Texas experienced approximately a 8% higher mortality rate of melanoma than the U.S. from 1986-1990 among white males (Miller et al., 1993), which is thought to be due to higher ultraviolet radiation in Texas, using U.S. data as a comparison as was done in most of these cohort studies, will inflate the observed SMR in Texas populations for this cancer type.

In the Union Carbide Chemicals & Plastics Company, Inc. study, all skin cancers were malignant melanoma and were concentrated in white manufacturing workers first hired before 1952 with long duration of employment. Geographic variation in melanoma rates would not have accounted for the 76% excess detected in this population. The SMR increased from 123 to 133 among Dow Chemical Company workers with 15 years or greater latency, but no analysis with duration of employment was presented.

Central Nervous System/Brain (157 cases)

For refinery workers, the number of observed deaths was approximately equal to the number of deaths expected. For the three manufacturing studies with four or more deaths and for both of the mixed plant studies, the SMR exceeded 100. Although not striking in magnitude, the central nervous system was the only cancer type with two or more individual SMRs above

150 in a plant category. The elevation of central nervous system/brain cancers was the subject of many studies.

Most of the Exxon Company USA (reference 10) brain cancer deaths had 30 or more years since first employment, but the small numbers precluded stable latency and duration trends. Dow Chemical Company studies indicated that the elevated risk was associated with first employment prior to 1945. In the Dow Chemical Company study, the SMR of 113 increased to 131 among workers with 15 or more years since first employment. Among Union Carbide Chemicals & Plastics Company, Inc. workers, the brain tumor mortality excess declined over time when compared to the U.S., but remained higher than expected. The Texaco study also reported more benign tumors than expected where 13 of the 20 benign tumors were brain tumors. In none of the studies could the brain cancer excess be attributed to a particular production area or exposure. A more complete discussion of these and other studies related to brain cancer is presented in Section 3.6.

All Lymphohematopoietic Cancers (464 cases)

Among refinery workers, all SMRs exceeded 100, and the summary SMR of 117 was of borderline statistical significance (95% CI=99-138). Only one of the five manufacturing SMRs exceeded 100 (Shell Oil Company), but was based on small numbers and the summary SMR remained below 100. For mixed type plant workers, both SMRs slightly exceeded 100 (but were not significant). The overall SMR for lymphohematopoietic cancers indicated a very slightly elevated, but stable risk estimate (SMR=104, 95% CI=95-114). The Mobil Oil Corporation and Shell Oil Company studies identified lymphohematopoietic cancer SMRs which increased for both increasing latency and duration of employment.

Lymphosarcoma/reticulosarcoma (49 cases)

The summary SMRs by plant type and for all workers for these lymphopoietic cancers were all below 100, but two of the three refinery SMRs indicated a moderate, albeit unstable elevation (Mobil Oil Corporation and Shell Oil Company). The Mobil study on Beaumont refinery workers showed no upward trend in SMRs with increasing duration of employment. The Shell Oil Company study indicated a significantly increasing trend by duration of employment, but the numbers were very small. While no excess was noted in the Union Carbide Chemical Company and Plastics Company, Inc. plant in Texas, an excess (SMR=140, 95% CI=104-187) was detected in their West Virginia plant, similar to, but older than their Texas operations (Rinsky et al., 1988). However, there was no pattern by latency or duration of employment.

Hodgkin's Disease (34 cases)

No data were available for manufacturing workers (information about Hodgkin's disease for Dow Chemical Company workers, the largest cohort included, were not provided for this category). The summary SMRs were elevated for refinery workers and for all workers (none was significant).

Leukemias (186 cases)

Two of the three individual SMRs for leukemias among refinery workers (Gulf Oil Corporation and Mobil Oil Corporation), and both studies among mixed plant workers (Texaco Inc. and Exxon Company USA) exceeded 100 compared to none of the SMRs for manufacturing workers. The summary SMR for refinery populations (SMR=127) was of borderline significance (95% CI=100-162). One exposure of concern among refinery workers is benzene which has been shown to be related to leukemias, specifically acute myelocytic leukemia (Austin et al., 1988).

Although there were no analyses by latency periods or duration of exposure in the Gulf Oil Corporation study, the SMR increased from 114 overall to 131 in male hourly workers employed at least one year. In the Shell Oil Company study, there was a non-significant increase in the leukemia SMR with duration of employment. The significant excess found in the Mobil Oil Corporation study did not demonstrate a latency or dose-response trend for leukemia. The U.S. rates used for the comparison population were noted to vary considerably from local rates.

Other Lymphohematopoietic (includes non-Hodgkin's lymphoma and other cancers of lymphoid tissue) (82 cases)

All summary SMRs for other lymphohematopoietic cancers exceeded 100, although none reached statistical significance. All three refinery SMRs for other lymphohematopoietic cancers exceeded 100 as did three of the five available manufacturing and mixed plant SMRs. There were no analyses by latency or duration of employment in the Gulf Oil Corporation or Ethyl Corporation studies. The Mobil Oil Corporation study described a latency, but not a dose-response trend. The Shell Oil Company study data did not demonstrate a trend by latency or duration of employment among the refinery workers, but such a trend was suggested among the chemical manufacturing workers. The Texaco Inc. population suggested increasing SMRs for increasing latency among maintenance and laboratory workers.

Overall Summary by Plant Type
Refinery

Based on three studies of refinery workers, there was a 7% deficit for total cancer (SMR=93, 95% CI=87-99). There were also significant deficits of buccal cavity/pharynx (SMR=55, 95% CI=36-80), all digestive (SMR=79, 95% CI=71-88), esophagus (SMR=53, 95% CI=34-80), colon and rectum (SMR=74, 95% CI=62-88), liver (SMR=44, 95% CI=25-71), and bladder cancer (SMR=59, 95% CI=39-87). SMRs exceeding 120 occurred for skin cancer (SMR=124, 95% CI=82-181), Hodgkin's disease (SMR=124, 95% CI=77-190), leukemias (SMR=127, 95% CI=100-162), and other lymphohematopoietic cancers (SMR=127, 95% CI=90-173). There was only one additional cancer category, all lymphohematopoietic cancer which exceeded 110 (SMR=117, 95% CI=99-138). Leukemias and all lymphohematopoietic cancer approached statistical significance in refinery workers.

Chemical Manufacturing Plants

For chemical manufacturing workers (based on five independent populations), significant cancer deficits occurred for the following cancer types: buccal cavity/pharynx (SMR=58, 95% CI=38-85), all digestive (SMR=84, 95% CI=76-93), stomach (SMR=57, 95% CI=40-79), colon and rectum (SMR=85, 95% CI=73-99), and prostate (SMR=74, 95% CI=58-94). SMRs $\geq$120 occurred only for skin cancer (SMR=129, 95% CI=94-173). Additional SMRs $\geq$110 occurred for kidney (SMR=115, 95% CI=85-152), central nervous system (SMR=119, 95% CI=93-151), and other lymphohematopoietic (SMR=111, 95% CI=51-211). None of the excesses was statistically significant.

Mixed Type Plants

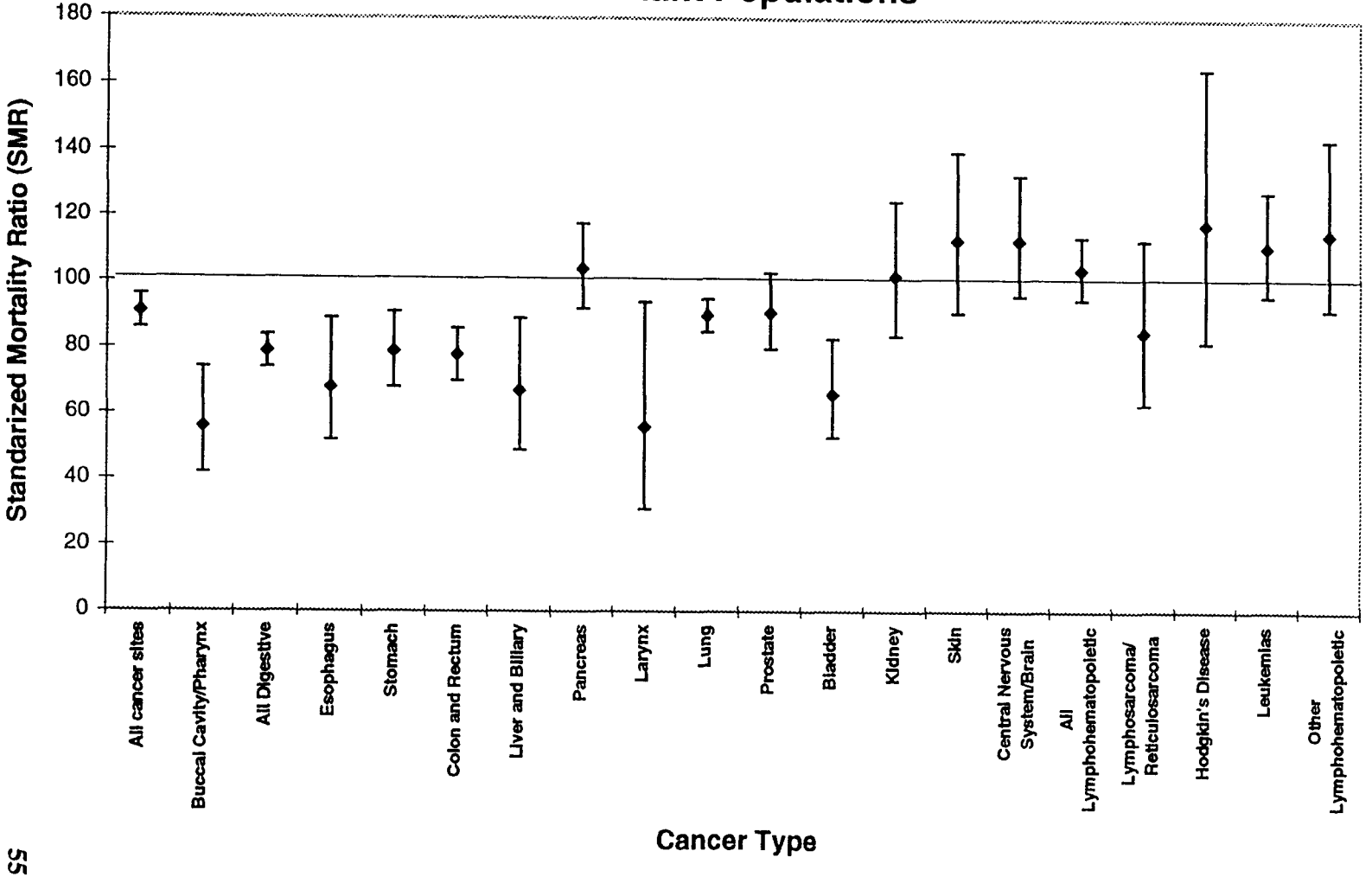
Based on the two populations where refinery and manufacturing operations could not be distinguished, significant deficits occurred for all cancers (SMR=78, 95% CI=73-83), all digestive cancers (SMR=74, 95% CI=66-83), stomach cancer (SMR=74, 95% CI=56-97), colon and rectum cancer (SMR=71, 95% CI=57-88), and lung cancer (SMR=64, 95% CI=57-72). The only SMR which equaled or exceeded 120 was for central nervous system/brain (SMR=120, 95% CI=87-162). Additional SMRs $\geq$110 only occurred for leukemias (SMR=117, 95% CI=91-151). Again, none of the elevated SMRs was statistically significant.

The results of the refinery and mixed plant populations can be compared to the review of petroleum industry employees by Wong and Raabe (1989). Wong and Raabe showed a significant deficit for total cancer, digestive, stomach and lung, similar to the experience of the mixed plant and refinery workers (for some sites) from this review. Wong and Raabe (1989) reported a nearly significant 10% excess of leukemias (95% CI=97-123), somewhat lower than the refinery (SMR=127, 95% CI=100-162) and mixed plant (SMR=117, 95% CI=91-151) workers in this summary. They reported a 15% excess for other lymphatic cancers (95% CI=95-138) compared to the 27% (95% CI=90-173) excess among refinery workers and a 5% excess among mixed plant workers (95% CI=73-147) calculated in this review. Similar to the results for refinery workers in this review, the overall SMR for brain in the Wong and Raabe (1989) review was not in excess (SMR=100, 95% CI=87-115).

All Workers

The summary SMRs and confidence intervals by cancer type for all workers are presented visually in Figure 4. For all workers combined from 11 plant populations in Texas, there was a significant 9% deficit for total cancer (SMR=91, 95% CI=86-96). Other significant deficits occurred for cancers of the buccal cavity/pharynx (SMR=56, 95% CI=42-74), all digestive (SMR=79, 95% CI=74-84), esophagus (SMR=68, 95% CI=52-89), stomach (SMR=79, 95% CI=68-91), colon and rectum (SMR=78, 95% CI=70-86), liver and biliary (SMR=67, 95% CI=49-89), larynx (SMR=56, 95% CI=31-94), lung (SMR=90, 95% CI=85-95), and bladder (SMR=66, 95% CI=53-83). There were no SMRs reaching at least 120. SMRs and associated confidence intervals which reached or exceeded 110 for all workers included skin (SMR=113,

Figure 4
Summary SMRs By Cancer Type:
11 Plant Populations



level, and in addition, the effect of sample size also can be ascertained. The narrower the confidence interval, the less variability was present in the estimate of the effect, reflecting a larger sample size. Conversely, the wider the confidence interval, the greater the variability in the estimate of effect, and the smaller the sample size (Hennekens and Buring, 1987).

In evaluating the role of statistical significance, it is important to bear in mind that statistical significance provides no information about whether or not the exposure under study is responsible for the observed effect. In order to assess whether or not an observed association is indeed causal, the association must satisfy the epidemiologic criteria for causality described above.

In addition to evaluating the role of chance, other alternative explanation for the findings must be considered. These include the possibility of bias or systematic error in the way persons were selected into the study population or in the way information was obtained or reported and the possibility of confounding, that is, the distortion of the apparent relationship due to unmeasured or uncontrolled factors that are associated with the exposure and independently affect the risk of developing the disease.

Epidemiologic Study Designs

Ecologic Studies

Ecologic studies provide the weakest evidence of causality, although they may be useful in generating hypotheses. The unit of observation in ecologic studies is the group rather than the individual. Disease rates, usually incidence or mortality, for defined geographic areas such as census tracts, are correlated with exposure data, such as extent of industrial activity in the same geographic area.

Weaknesses of the ecologic study design include the possibility of invalid inferences because observations are based on proxy measures of exposure and disease rather than on individuals (i.e., the ecologic fallacy); unavailability of data to control for confounding factors in the analysis; and lack of specific and detailed measures of exposure.

Proportional Mortality/Morbidity Studies (PMR)

PMR studies may be useful as a preliminary analysis to investigate disease excesses and deficits or when the population at risk cannot be enumerated but information is available on disease occurrence, e.g, the number of deaths or incident cases. The most common circumstance calling for a PMR study is the availability of death certificates but the absence of other information needed to conduct a cohort or case-control study.

The PMR index compares the proportion of dead (or diseased) persons from an exposed population who have been assigned one or more specific causes of death (or disease) with a

95% CI=91-140), central nervous system/brain (SMR=113, 95% CI=96-133), Hodgkin's Disease (SMR=118, 95% CI=82-165), leukemias (SMR=111, 95% CI=96-128), and other lymphohematopoietic cancers (SMR=115, 95% CI=92-144), but none of these was statistically significant at p<0.05.

An excess of skin cancer occurred in the refinery and manufacturing workers, but not in the mixed plant workers. The leukemia elevation occurred in the refinery and mixed plant workers; it was notably absent in the manufacturing group. A small excess of central nervous system/brain cancer, although not statistically significant, was consistently found in the manufacturing and mixed type workers, but no excess occurred in any of the refinery studies.

3.3 Industry-based Case-Control Studies

There were eight industry-based case-control studies of cancers other than those limited to brain cancer/tumors only (these are discussed separately in Section 3.6). The National Cancer Institute (NCI) and the National Institute for Occupational Safety and Health (NIOSH) conducted a case-control study of leukemia, stomach, and brain tumors among Oil, Chemical, and Atomic Workers (OCAW) members at three oil refineries (Thomas et al., 1984). Elevated odds ratios were detected for leukemia among refinery workers that increased with increasing duration of employment for persons in the treating (OR=1.6, 90% CI=0.7-3.8) and boilermaking (OR=1.5, 90% CI=0.6-3.9) exposure categories, for stomach cancer in the lubricating oil exposure category (OR=1.7, 90% CI=1.0-3.1), and for maintenance and laboratory workers (OR=4.5, 90% CI=1.7-12.0). There were no elevations for brain cancer with increasing duration of employment in any of the exposure categories. However, these results were based on very small numbers when subdivided into exposure categories and subject to incomplete case ascertainment.

Based on excesses noted for renal and lung cancer in a cohort study (Bond et al., 1985a), Dow Chemical Company conducted a series of case-control studies to attempt to identify possible etiologic exposures. Based on only 26 kidney cancer cases, the first case-control study (Bond et al., 1985c) reported significant odds ratios for workers in the chlorine production area (OR=3.8, 90% CI=1.3-10.9) and elevated odds ratios for presumptive exposures considered to occur in this area--asbestos (OR=3.0, 90% CI=1.2-7.1) and caustic (OR=2.9, 95% CI=1.2-7.0), but not chlorine. Four reports (Bond, 1985; Bond et al., 1986; Bond et al., 1987; Bond et al., 1991) pertained to lung cancer and compared the exposure histories of 308 workers who died of lung cancer to 616 living and decedent controls (nested from the cohort of Dow Chemical workers (Bond et al., 1985b). Smoking data were available on approximately 80% of the cases and controls. Highly significant odds ratios were detected for smoking which increased with increasing intensity/duration levels of smoking (Bond, 1985). Of 38 chemical exposures that were considered (including asbestos, benzene, beryllium, carbon tetrachloride, wood dusts), only the odds ratios for butyl mercaptans (OR=4.6, 95% CI=1.0-20.6), heat (OR=1.5, 95% CI=1.1-2.0), and sulfur dioxide (OR=1.4, 95% CI=1.0-1.9) were statistically significant. There was a significant dose-response trend for heat and sulfur dioxide when compared to decedent, but not living controls (Bond et al., 1986). The expected intensity/duration association of lung cancer

with asbestos exposure was not demonstrated in this study. In the third lung cancer report, (Bond et al., 1987), the authors investigated the relationship of lung cancer to Vitamin A in the same case-control population. Telephone interviews with participants or next-of-kin were conducted to determine the frequency of consumption of 29 food items in the three to five years prior to the case's lung cancer diagnosis. A dose-response trend was seen for increased lung cancer and lower levels of vitamin A with both decedent and living controls with adjustments for smoking, education level, and vitamin A supplements. The odds ratio was statistically significant only among living controls (low Vitamin A OR=2.0, 95% CI=1.2-3.5) and the effect was greatest among smokers. Findings were similar, but more pronounced, using carotenoids. In the fourth lung cancer report, analyses of different measures of hydrogen chloride exposure (duration, highest, cumulative) showed no association with increased lung cancer risk. All odds ratios were between 0.8 and 1.2; all confidence intervals included 1.0, and no trends were detected (Bond et al., 1991).

Two dissertations (Khalfan, 1985; Aldrich, 1985) utilized data from the Buffler et al., 1984 respiratory cancer case-control study to examine lung cancer among petrochemical workers. Khalfan (1985) detected non-significant decreased risks of lung cancer among workers ever employed in oil refinery (OR=0.84) or when classified by usual employment in oil refining (OR=0.77). Aldrich confirmed the major risk factor for lung cancer to be cigarette smoking (OR=9.8; 95% CI=8.2-11.7), and estimated that smoking accounted for 86.5% of the incident lung cancer cases in the Texas Gulf Coast study area. Workers in the petroleum industry smoked significantly less than workers in other industries. Industry restricted smoking policies may have explained the low risk of lung cancer in the petrochemical workers.

Overall, the case-control study design, especially when nested in an industrial cohort, or conducted in an entire community where the prevalence of exposure is relatively common, is a useful and efficient design to more rigorously explore possible etiologic exposures for cancer. However, if the exposure is ubiquitous within an industrial plant or very rare in a community, the case-control approach would not be effective in determining risk in these settings.

3.4 Morbidity Studies

Four morbidity studies were conducted in four industrial populations. Union Carbide Chemical Company conducted a cross-sectional survey to compare health effects between 36 ethylene oxide operators and 39 operators of other units (Joyner, 1964). Five cases of benign and malignant neoplasms occurred from 1955-1962 among ethylene oxide operators compared to 7 among control operators. The data were insufficient to draw strong conclusions due to the small sample size, incomplete ascertainment of cancer, and no follow-up or latency considerations. Zadeii (1987) conducted a cross-sectional study comparing the prevalence of cancer among 1,803 workers exposed to asbestos for 15 years or longer to the cancer experience of the Connecticut Tumor Registry. However the sample only included workers with abnormal chest x-rays and only 55% of those eligible. Data were not available to control for potential

confounding; therefore, the evidence was not sufficient to support any etiologic relationship between asbestos exposure and various cancers. Shell Oil Company initiated a morbidity prevalence study (Tsai et al., 1990) in response to a possible excess of leukemia and lung cancer, and a dose-response effect for heart disease reported by Enterline et al. (1990) in a historical cohort study of workers with potential exposure to epichlorohydrin. In this study, the cancer morbidity experience in two cohorts of workers with potential exposure to epichlorohydrin (survivors who remained employed from the original Enterline study ["Enterline cohort"] and those later hired ["Shell cohort"]) was compared to an internal comparison group. No morbidity events for leukemia or cancer of the respiratory system occurred in either cohort. The overall cancer SMR was 93 for the Enterline cohort and 101 for the Shell cohort. A second Shell Oil Company historical cohort study (Tsai et al., 1992) ascertained the morbidity experience from 1981-1988 of 3,422 Shell Oil Company Deer Park refining and petrochemical plant employees. The overall cancer SMR was 108 (95% CI=88-132) based on 101 cancers. The number of site-specific cancers was limited and none was statistically elevated. This study was not designed to specifically ascertain cancer outcomes and included only active employees. ***Overall, incomplete ascertainment of cancer incidence, other methodologic limitations, or small numbers, limited the weight given to the four morbidity studies in relation to cancer.***

3.5 Proportionate Mortality Ratio (PMR) Studies in Labor Union Workers

Four PMR studies were conducted by NIOSH and OSHA among the Oil, Chemical and Atomic Workers (OCAW) International Union, and one among the International Union of Operating Engineers. A PMR study of active OCAW union members from three oil refineries in Texas identified statistically significant excesses of digestive organs, respiratory, skin, and brain cancer among white males (Thomas et al., 1980). This study was limited by the inclusion of only active workers. Two letters to the editor suggested the results were concentrated in low survival cancers perhaps because of company benefit plans (Divine, 1980) and detailed the problems of PMR studies based on an incomplete set of deaths (Wong and Tabershaw, 1980). A PMR study of active and retired members of the OCAW union who worked at the same three oil refineries in the Beaumont/Port Arthur area also identified a statistical excess of brain cancer, but noted that PMRs for lymphohematopoietic cancers were elevated as well (Thomas et al., 1982a). A third PMR study was conducted by NIOSH to explore excesses noted among OCAW members from the Texas City local (Reeve et al., 1982). The strongest association was for skin cancer (melanoma). A fourth report (Thomas et al., 1982b) focused only on brain tumors at the three Texas oil refineries. The significantly elevated PMRs for brain cancer occurred when the U.S. was used as the comparison population, but diminished in magnitude and became non-significant when compared to the local two-county area. To determine if cancer excesses noted in OCAW union members existed among members of the International Union of Operating Engineers serving the chemical, petrochemical, and construction or maintenance industries, Nicholson et al. (1982) conducted a PMR study for Texas City workers. Elevated PMRs occurred for brain and lung cancer in some analyses.

As described in Appendix A, PMR studies are quite weak methodologically. All of the above studies suffered from the usual weaknesses of PMR studies which lack population-at-risk

data needed to compute rates, depend on a complete ascertainment of deaths (an assumption clearly not met in most of these studies), and are by definition sensitive to proportional causes of other deaths. These limitations were very adequately addressed by the authors who recognized these studies as hypothesis-generating in their purpose. The brain cancer excesses led to the initiation of further studies using more scientifically rigorous study designs as described in Section 3.6 below.

3.6 Brain Cancer/Tumor Studies (other than PMR studies)

Brain cancer among chemical/petrochemical workers has been the focus of a substantial number of studies and updates. Studies which limited their focus to brain cancer as well as other relevant studies which report data on various cancer types including brain cancer data are discussed together here in a separate section (other than PMR studies discussed in Section 3.5 above). The authors of these studies recognized the possible misclassification of brain cancers and therefore also considered brain tumors as a relevant diagnosis.

The summary SMR analysis (Section 3.2), based on the overall cohort mortality studies included data on brain cancer from 11 independent plant populations. The overall summary SMR for brain cancer was slightly elevated (SMR=113, 95% CI=96-133). Of these 11 plants, only five represented populations with 10 or more brain cancer deaths; two were in chemical manufacturing populations (Union Carbide Chemical and Plastics Co., Inc., Dow Chemical Company) and the remaining three in refining or mixed plant workers (Gulf Oil Corporation, Texaco Inc., Exxon Company USA). All studies pertaining to brain cancer in these five plant populations are discussed below.

Eight studies have been conducted pertaining to brain cancer among Union Carbide workers. As an initial investigation of a brain cancer excess, the authors from OSHA and NIOSH reported 18 primary brain cancer deaths among male workers at one Texas petrochemical plant from 1965-1980 (Alexander et al., 1980) and updated to 20 deaths in the second report (Alexander et al., 1982). These two reports include the initial enumeration and histologic confirmation of brain tumor cases by OSHA/NIOSH resulting from a cluster report. In response to the suspected excess of brain tumor deaths, two historical cohort studies on the same population were conducted by NIOSH and Union Carbide. The NIOSH cohort (Waxweiler et al., 1983) included 7,595 white and nonwhite males who were ever employed at the Union Carbide Texas City plant from 1941-1977. Among hourly employees (n=6,051), the SMR was elevated for brain cancer (SMR=181, 95% CI=96-309), for benign brain tumors (SMR=286, 95% CI=35-1032), for unspecified brain neoplasms (SMR=235, 95% CI=64-603), and for total brain tumors (SMR=198, 95% CI=119-309) which increased with increasing duration of employment. An independent analysis of the same cohort of white males by Union Carbide Corporation (Austin and Schnatter, 1983a) yielded elevated SMRs among hourly workers with more than six months employment for brain cancer (SMR=200, $p<0.05$), unrelated to length of employment and for benign and unspecified neoplasms (SMR=346, $p<0.05$).

NIOSH (Leffingwell et al., 1983) and Union Carbide Corporation (Austin and Schnatter, 1983b) then independently conducted case-control studies of brain cancer deaths to try to identify possible exposures contributing to an apparent excess of brain tumors in the cohort study. NIOSH (Leffingwell et al., 1983) conducted a nested case-control study of 17 cases of gliomas each matched to six controls selected from others in the cohort alive or dead (but not due to neoplasms). No association was found between gliomas and duration of exposure to any specific chemical. The elevated odds ratio for residence in La Marque was significant. In parallel, Union Carbide Corporation (Austin and Schnatter, 1983b) conducted a decedent case-control study on 21 confirmed brain tumor deaths. Controls were 160 males, half of whom died of non-cancer causes and half of whom were selected from all deaths chosen randomly among decedents from the company. The proportion of cases exposed to five potentially carcinogenic chemicals (benzene, ethylene dichloride, ethylene oxide, diethyl sulfate, vinyl chloride) were approximately the same for cases and controls. Although both studies identified elevated (although most were not significant) odds ratios from a series of potential exposures, there was no latency or dose-response effect and no biologic plausibility supported by toxicology studies. NIOSH further reviewed the brain cancer experience in a different plant, the Union Carbide Seadrift Plant. Based on only one brain cancer death reported and confirmed during the study years, the results did not further elucidate any occupational exposure as a cause of brain cancer (Reeve et al., 1983a).

Teta et al. (1991) updated their cohort mortality study by adding six years of observation (1978-1983) and expanded their cohort to include nonwhites and all Texas City workers ever employed from 1941-1983. Elevated SMRs occurred among hourly workers for brain cancer (SMR=181, 95% CI=106-289), and for benign and unspecified brain tumors (SMR=280, 95% CI=114-577). There was some diminution in the brain tumor SMR over time compared to the U.S., but remained higher than expected (update period 1978-1983 SMR=147 compared to earlier period 1950-1977, SMR=224). Although the authors reported higher SMRs for men with longer employment and time since first hire, there was no clustering of cases within production work areas (cases worked in 8 of 15 major production units with no more than three cases with assignments to any one work area) or by maintenance craft. There was a reported deficit of brain cancer (SMR=67, 95% CI=45-98) in a Union Carbide Chemical West Virginia plant where operations were older, but quite similar to those of their Texas plant (Rinsky et al., 1988).

Specific investigations of brain tumors in Dow Chemical USA employees were conducted in one historical cohort study (Reeve et al., 1983b) and two case-control studies (Bond et al., 1982; Bond et al., 1983). A review of NIOSH/OSHA methodology and preliminary results was also published (Reeve et al., 1982). NIOSH identified twenty-five brain tumors from a four county area (Brazoria, Harris, Galveston, and Matagorda) and matched these individuals against Dow Chemical Company employment records (Reeve et al., 1983b). Mortality was compared to that expected based on a 5% cohort sample of white males employed at Dow Freeport from 1940-1977. Adjusting for migration, the SMR for those hired prior to 1945 was 184 (no statistical testing performed). The SMR diminished for those hired subsequent to 1945. To determine possible relevant exposures for further study, Dow Chemical U.S.A. conducted two case-control studies of Dow-Freeport male employees who died due to brain tumors from 1950-

1979 and were hired from 1940-1979 (Bond et al., 1982). Two comparison groups of alive and decedent employees were selected. No significantly elevated odds ratios occurred for specific department assignments or chemical exposures. Cases were significantly more likely than controls to have been hired before 1950, but employed more often 1-5 years rather than more than 10 years.

Dow Chemical Company later conducted three cohort mortality studies (discussed in Sections 3.1 and 3.2) which included information on brain cancer (Bond et al., 1985a; Bond et al., 1985b; Olsen et al., in press). In the most recent cohort update (1940-1989), the brain cancer SMR of 113 (95% CI=82-151) was not statistically significant, but increased to 131 (95% CI=94-179) among workers with 15 or more years since first employment.

Gulf Oil Corporation reported the brain tumor experience from an historical cohort study of 15,698 males who were ever employed at the Texas oil refinery from 1935-1978 (Wen et al., 1981) and in a second updated report (Wen et al., 1982). No brain tumor excesses were found to be statistically significant. The SMR for total brain tumors was 92 for white males and 143 for nonwhite males. For both whites and nonwhites, SMRs increased with increasing duration of employment.

No Texaco Inc. studies were limited specifically to brain tumors, but the three historical cohort mortality studies provide relevant data. In the first study of white males employed at least five years during 1947-1977 (Divine et al., 1985), the brain cancer SMR was 111 (95% CI=75-157) and was 148 (95% CI=91-229) for benign tumors, of which 13 of the 20 were brain tumors. In the second analysis which incorporated job histories, the SMR was significantly elevated in the laboratory subcohort in those who worked less than 10 years with a latency of at least 20 years (SMR=408, 95% CI=131-952). In the third cohort study limited to production and pipeline workers, there was no excess of brain cancer (Divine and Barron, 1987).

As part of the Exxon Company USA cohort studies, data was also provided on brain/central nervous system (CNS) mortality. In the most recently updated study (Shallenberger et al., 1992) based on 12 brain cancer/CNS deaths, the SMR for the Baytown plant when compared to Texas was 156 (95% CI=80-272), and most of the brain/CNS cancer deaths occurred with at least 30 years latency.

In addition to the studies in these five plant populations, NCI and NIOSH conducted a case-control study of cancers (including brain) among OCAW members at three oil refineries (Thomas et al., 1984). There was a significant odds ratio for brain cancer among workers in the Receipt and Movement work category (OR=2.8, 90% CI=1.1-6.8), but the median duration of employment for cases was only 3.0 years compared to 13.8 years for controls.

In summary, there have been numerous studies using analytic epidemiologic study designs which have examined brain cancer among chemical and petrochemical workers. When excess brain cancer mortality has been reported, no workplace exposure or particular production area has been demonstrated to account for the excess. Further, the excess often

did not follow a dose-response or latency gradient, further clouding the attribution to an occupational exposure.

3.7 Colorectal Cancer Studies

Because of the special focus on colorectal cancer by one company using various study designs, the four studies pertaining to colorectal cancer are grouped together in this section for discussion. Although not evident from the overall Exxon Company USA cohort mortality study (Shallenberger et al., 1992), Exxon Biomedical Sciences, Inc. in collaboration with Exxon Chemical Americas, has reported an excess of colorectal cancer or adenomatous polyps among workers on a polyolefin unit devoted to the manufacture of polypropylene in Baytown. These studies were initiated based on a reported cluster of colorectal cancers. The initial study (Acquavella et al., 1988) described an excess incidence of colorectal cancer compared to the Dallas area (standardized incidence ratio (SIR)=5.6, 95% CI=2.2-11.5) which increased with longer latency and was restricted to workers employed during the earlier plant periods. Based on this study, a screening program was initiated for all current and former employees from the polyolefin unit (Acquavella et al., 1989). Elevated prevalence rate ratios (PRR) of adenomatous polyps (a precursor to colon cancer), were detected for all workers (PRR=1.4, 90% CI=0.9-2.2) and for process/mechanical workers (PRR=1.3, 90% CI=0.8-2.3) compared to a non-Exxon population screened at the same clinic. All polyps of unknown histology that were 1.0 cm or greater were assumed to be adenomatous. The prevalence ratios were largest among those workers with at least 5 years employment on the polyolefin unit; however, results were limited by low participation, possible limitations associated with the comparison group (Dougherty, 1990; Gibbs, 1990), and the potential for uncontrolled confounding (e.g., diet and family history of polyps). The third study (Acquavella et al., 1991) was a case-control study of 24 cases (23 with adenomatous polyps, 1 with colorectal cancer) and controls were selected from the same screening program. The results showed cases had a higher exposure to base plant polymers (OR=2.6, 90% CI=1.1-6.3) and higher exposure to recent finishing additives (OR=4.8, 90% CI=1.5-15.3) compared to controls. However, the elevated odds ratios did not follow a dose-response trend and the study may have been subject to selection bias if the more highly exposed workers were more likely to participate in the screening program. There was no control for several potentially important confounders (e.g., diet and genetic factors). A fourth study (Acquavella and Owen, 1990) was conducted in a cohort of workers at two polypropylene pilot plants (one in Texas), which were within the same company, but separate from the original unit where the cluster was detected. No cases of colorectal cancer occurred in the Baytown plant. ***The associations detected in three of the Exxon Biomedical Sciences, Inc. studies yielded persistent elevations for colorectal cancer or adenomatous polyps; however, the lack of a dose-response effect, the choice of a screening comparison population, and incomplete control for confounding, preclude making etiologic conclusions about this apparent excess. Exxon Biomedical Sciences, Inc. and Exxon Chemical Americas are continuing to study these workers and another report regarding screening results, not eligible for inclusion within the time frame of this review, has recently been published (Lewis et al., 1994).*** [However, for completeness, the present authors note that this report indicated an elevated incidence rate ratio (IRR), which was not statistically significant, for adenomatous polyps (IRR=1.8, 90% CI=0.7-4.8) when

polypropylene manufacturing workers were compared to non-Exxon employees screened at the same clinic. No trends in IRR by job category were detected.]

4.0. NON-INDUSTRY BASED STUDIES: SUMMARY OF POPULATION AND HOSPITAL-BASED STUDIES BY EXPOSURE OR CANCER TYPE

In this section, a summary of the results of studies conducted in non-industrial populations in Texas is presented. These pertain to environmental factors (drinking water and air pollution), lifestyle studies (smoking, exercise, diet, alcohol), genetic factors (familial aggregation), special population groups (childhood cancers), and the investigation of occupational/environmental factors in the development of specific cancers (hospital or population-based case-control studies).

4.1 Environmental Studies

There were 16 environmental epidemiologic studies pertaining to drinking water (two published and six unpublished theses or dissertations) and air pollution (six published and two unpublished). In all of these studies, the investigators used the ecologic study design. As discussed in Appendix A, the ecologic study design is useful in generating hypotheses or in situations where insufficient variation in exposure precludes analytic studies. In the situation in which the following ecologic studies were conducted the overall strength given to conclusions based on these studies was weakened. Six of the eight drinking water studies were unpublished and therefore not previously subject to peer review.

Drinking Water

Two published ecologic studies examined the relationship between selenium and trihalomethanes and cancer. In the first (Cech et al., 1984), the overall age-adjusted cancer mortality rates (1964-1976) for counties and cities in Texas were compared with concentrations of selenium in drinking water to explore the hypothesis that selenium is an essential micronutrient and possible cancer inhibitor. Visual inspection of maps showed some correlation between higher selenium levels and lower cancer mortality, especially in the Panhandle area. Based on limitations noted by the authors (no controlling for other possible confounding factors such as socioeconomic status, occupation, smoking, or length of residence), using current levels of selenium to estimate earlier exposures, and possible sampling errors, the evidence remains incomplete. A second ecologic study (Henry, 1982; Cech et al., 1987) compared urinary tract cancer over five year intervals from 1940-1974 by duration of exposure to source of treated drinking water in the Houston, Texas area. The primary environmental exposure of interest was trihalomethane byproducts of chlorination of surface water. The study did not support a trihalomethane/urinary tract cancer causal effect, but the authors recommended periodic monitoring for urinary tract cancer mortality, especially in white females. Other study results (Eccleston, 1978) did not support source of drinking water (surface, ground or mixed) in Houston, Texas as a cause of gastrointestinal and urinary tract cancer (1940-1969). A pilot study (French, 1982) was conducted by testing rice, soil, and water samples for dioxin and aflatoxin and compared measurements to gastrointestinal and urinary tract cancer rates in Brazoria County census tracts. Non-significantly elevated SMRs were seen in rice-growing versus non-rice growing census tracts for gastrointestinal and male urinary tract cancers, but neither dioxin nor aflatoxin was found in the samples. Average annual age-adjusted mortality rates (1964-1976) for

total, lung, gastrointestinal, and urinary tract cancers were compared by source of drinking water in 16 cities in Texas (Bogdan, 1982). There was no effect seen between cancer mortality and trihalomethane measurements in the 16 cities. This study was a hypothesis generating study; a more analytic study would be required to determine if any excess mortality was related to drinking water or to other personal factors not taken into account in this ecologic study.

Mortality rates for cancer causes of death (total cancer, digestive, urinary tract, lung) and non-cancer causes in Texas cities with a population larger than 1,500 people were compared by source of drinking water (Hollingsworth, 1982). Although the author concludes that cancer mortality varied by water source in some analyses (e.g., along the Gulf Coast), the study was too imprecise to link high cancer rates with use of surface water. There was no control for potential important confounders such as diet, smoking, family history of cancer, and occupation. To follow up on previous reports of an association between gastrointestinal cancers and fluoride in drinking water, Washington (1982) utilized correlation and multiple regression to examine cancer mortality for Texas counties (consisting of at least 1,000 residents) and fluoride measurements in drinking water. Variation in gastrointestinal tract cancer mortality rates was unrelated to variation in fluoride levels. As with the other ecologic studies, there was no control for potentially important confounders such as diet.

Air Pollution

Eight ecologic reports were reviewed pertaining to air pollution. Hoover and Fraumeni (1975) detected excess rates for bladder, lung, and liver cancer among males in 139 counties where the chemical industry was prominent. Although not limited to Texas (or air pollution), several Texas counties were identified among chemical counties with high cancer rates (Galveston, Jefferson, Orange, Harrison). This study was one of the first reports to suggest occupational chemical exposure as a possible cause of elevated cancer-specific mortality in several Texas counties and precipitated further epidemiologic studies.

Agu et al., 1980 examined average annual age-adjusted mortality rates for multiple myeloma in 31 state economic areas in East Texas. Significant correlations were detected for multiple myeloma and usual employment in beauty shops, carpentry, and agriculture. A significant negative correlation was detected for multiple myeloma and usual employment in the mining industries.

A series of studies explored the relationship between air pollution and respiratory cancer in the Houston, Texas area. Based on a methodologically weak ecologic study, Macdonald (1976a) strongly attributed the increased risk of lung cancer to environmental exposures. Walker et al. (1982) reanalyzed Macdonald's data, using an air pollution mutagenicity index and noted a significant correlation with lung cancer in white males. Due to the limitations in the Macdonald (1976a) study, the use of 1978 air pollution measurements for 1965-1967 deaths, and restriction of analyses to white males, the strength of the Walker et al. (1982) analyses was weakened. Marmor (1978) attempted to stratify Macdonald's data by income level for three levels of air pollution, but mistakenly used areas of cancer mortality for classes of air pollution

(Shirts, 1982). In an attempt to confirm or clarify Macdonald's assertion, Buffler et al. (1988) used linear regression to examine the relationship between census tract lung cancer mortality rates and census tract total suspended particulates (based on measurements ten years prior to death while controlling for median age, an age-smoking index, and two socioeconomic variables not strongly correlated with air pollution). Air pollution was associated with less than 5% of the total variation in intraurban lung cancer mortality. The Buffler et al. study (1988) was important in clarifying earlier reports, but concluded that further ecologic studies would not continue to advance knowledge about air pollution and lung cancer.

Grimardi et al (1989), in an unpublished report, examined mortality for two Texas counties containing Union Carbide plants (Calhoun and Galveston counties). Lack of data on smoking and environmental exposure by geographic area diminished the strength given to excesses that were noted.

Limitations of all ecologic analyses include the inability to control for many potentially important confounders, the assumption that exposures of a geographic area, e.g., census tract, is uniform for all individuals within that geographic area, and the unavailability of confirmation of death certificate causes of death. In general, these environmental studies did not support drinking water or air pollution as a cause of cancer, but limitation in study design precludes drawing firm conclusions. Drinking water and air pollution as risk factors for cancer remain inadequately studied in Texas.

4.2. Lifestyle Studies

This review included four lifestyle studies pertaining to smoking, exercise, diet, and alcohol. A previous study investigating the relation of lung cancer to Vitamin A in an industrial population was reviewed in Section 3.3. Holck et al. (1982) conducted a cross-sectional survey of Mexican American women in U.S.-Mexican border counties. In all groups, smoking prevalence among Mexican-American women was less than Anglos. Correlation of smoking prevalence with Texas lung cancer mortality data by the original study investigators pointed to smoking habits as an important factor in explaining the different mortality rates. Blair et al. (1989) conducted a historical cohort study which examined physical fitness and cancer mortality (as well as other causes of death). Using physical fitness (based on maximal treadmill exercise test) as a surrogate for physical activity, there was a significant decreasing trend in the age-adjusted cancer mortality rate by increasing quintiles of fitness. Two case-control studies examined diet (specifically Vitamin A, retinol, and carotene) and laryngeal cancer (Mackerras et al., 1988; Falk et al, 1989). The authors concluded that low carotene intake, cigarette smoking, and alcohol (4 or more drinks per week) increased the risk for laryngeal cancer (Mackerras et al., 1988; Falk et al., 1989). The studies were well-conducted, but were based on living cases which comprised only approximately half of the original laryngeal cancer cases. It is interesting to note the consistency of the dietary risk for low intake of carotene (odds ratio approximately=2) for laryngeal and lung cancer which was a stronger risk factor among smokers (Mackerras et al., 1988; Bond et al., 1987).

Overall, there was a paucity of studies pertaining to lifestyle factors in relation to cancer. However, the reviewed studies demonstrated a significant contribution of lifestyle variables to cancer. Although not included in this section, smoking has been documented in Texas populations as a strong risk factor for lung cancer in men and women, (see Section 4.5 on occupational/environmental case-control studies).

4.3. Genetic Studies

Seven genetic studies utilizing various study designs were published. Weiss et al. (1986) conducted a historical cohort study which was based on vital events of more than 300,000 Mexican-Americans in Laredo, Texas from 1900-1984 by examining civil and church records of birth, marriage, and death. A statistically significant, however, small excess of familial cancer was detected for total cancer, for cancer of the breast, and a smaller excess for ovarian cancer. Using data collected for Buffler et al.'s (1984) case-control study of respiratory cancer, Shaw et al. (1991) examined the relationship of lung cancer to the proportion of first degree relatives with any cancer and with lung cancer. The study population consisted of 937 cases of primary lung cancer in whites aged 30-79 first diagnosed during 1976-1980 among residents of six Gulf Coast Texas Counties and 955 population-based controls. Risks were higher for first degree relatives with lung cancer (OR=2.8 for lung cancer with two or more relatives. 95% CI=1.2-6.6), tobacco related cancers (OR=1.5 for two or more relatives, 95% CI=0.9-2.7), and any cancer (OR=1.6 with three relatives, 95% CI=1.0-2.5).

Four studies examining the genetic contribution to cancer were conducted using patients at M.D. Anderson Cancer Center in Houston, Texas. Bondy et al. (1991) utilized a family study design to determine the genetic contribution to childhood brain tumors by comparing the cancer experience of study families to that of the Connecticut Tumor Registry. The study included 230 children who had a brain tumor diagnosed before 15 years of age and were referred to M.D. Anderson Hospital between 1944 and 1983. No excess of total cancer was found among first or second degree relatives, overall, or by relationship type. Elevated standardized incidence ratios (SIR) were detected for colon cancer among first degree relatives (SIR=3.1, 95% CI=1.0-7.2) and was even more pronounced, although unstable, among siblings (SIR=12.5, 95% CI=1.4-45.2). Overall, heritable factors were found in 4% of study families. Spitz et al. (1991) conducted a case-control study of 385 histologically confirmed cases of prostate cancer seen at M.D. Anderson hospital from 1985-1989 and 385 male control patients with other cancers. Family history of prostate cancer was positive for 13% of cases and 5% of controls (p=0.01). The age-adjusted odds ratio for men with a first degree relative with prostate cancer was 2.4 (95% CI=1.3-4.5). Strong et al. (1992) compared the frequency of cancer in families and in specific relationships to that of the Connecticut Tumor Registry in a cross-sectional analysis. Included were 159 children less than 16 years of age with a diagnosis of soft-tissue sarcoma at M.D. Anderson Hospital during 1944-1976 who survived three or more years and were diagnosed five or more years prior to onset of the study. Elevated SIRs were detected for first degree relatives with cancer (SIR=1.6, 95% CI=1.1-2.3) and for siblings (SIR=4.1, 95% CI=1.6-8.4) Genetic analyses revealed that the familial cancer could best be attributed to a rare autosomal dominant gene. Bondy et al. (1992) conducted a cross-sectional genetic study to compare the family

history of cancer among 50 white, 46 black, and 49 Hispanic women with breast cancer referred to M.D. Anderson Hospital from 1985-1989 to that expected from the Connecticut Tumor Registry (black and white) and the New Mexico Tumor Registry (Hispanic). There was an elevated risk of breast cancer in first degree relatives, which occurred before age 45 for blacks (SIR=4.1, 95% CI=1.1-10.4), for whites (SIR=4.5, 95% CI=1.2-11.4), but not for Hispanics (SIR=0.9, 95% CI=0.0-5.3). The attribution of a deficit in breast cancer among Hispanics to genetic expression rather than to cultural influences cannot be made with certainty from this study. And finally, evidence of a genetic component to cancers among the mentally retarded (Acterberg et al., 1978) based on a proportionate mortality ratio study, was insufficient to justify any conclusion.

In the reports of these studies, a genetic contribution to cancer was suggested, but could have accounted for only a small portion of the cases. Further, the genetic attribution was based on familial aggregation of cancers. In addition to genetics, families also share common socio-cultural and environmental characteristics, so that familial patterns are not necessarily genetic.

4.4. Childhood Cancer Studies

Eight studies were conducted on childhood cancer in Texas. Five of these were case-control studies which explored occupational associations with childhood cancer. No statistically significant associations with parental occupation and cancer were detected in a hospital based case-control study of cancer at Texas Children's Hematology Clinic (Zack et al., 1980), but question exists as to the appropriateness of the control group. The selection of parents, their siblings, and neighbors may not have achieved enough variation in potential occupational exposures. Selection of control parents with children followed at the hematologic clinic, but without cancer, may have been too close diagnostically to the cases to have been a suitable control group. A population-based case-control study was conducted on 157 children less than 15 years of age who died in Texas from neuroblastoma during 1964-1978 and 314 controls randomly selected from all live births in Texas to examine the distribution of paternal occupation as recorded on the child's birth certificate (Spitz and Johnson, 1985). No effect was found for paternal age, mean maternal age, prenatal care, illegitimacy, or urban versus rural residence. In an occupational cluster analysis, an elevated odds ratios (OR) were found for the "aromatic and aliphatic hydrocarbon" group (OR=3.2, 95% CI=1.1-8.9) which included electrical and electronic workers. Exposure in this study was implied by job title and was not specific to electric and magnetic field exposure (i.e., could also include hydrocarbon exposure). Using a similar study design, Johnson (1985) and Johnson et al. (1987) investigated the relationship between paternal occupational exposure (as defined by previous studies) to hydrocarbons and childhood central nervous system tumors (intracranial and spinal cord). This case-control study included 499 children who died of central nervous system tumors before the age of 15 during 1964-1980 and 998 randomly selected control birth certificates. For overall hydrocarbon-related occupations or most specific jobs associated with hydrocarbon exposure, there were no significant associations. Significant odds ratios were found for printers and graphics arts workers (OR=4.5, 95% CI=1.4-14.7) and chemical and petroleum workers with high exposure levels (OR=3.0, 95% CI=1.1-8.5).

Johnson and Spitz (1989) investigated the association between childhood nervous system tumors and paternal occupations at the time of birth involving potential exposure to low frequency electromagnetic fields (EMF). An elevated odds ratio was found among paternal employment in industries with potential EMF exposure (OR=1.6, 95% CI=1.0-2.8) and a risk of 3.5 (CI=1.0-12.1) was detected for fathers who worked as electricians. There was no control for potential confounding due to lifestyle variables and to exposure to diverse chemicals likely to be found in both the electrical and electronic industries.

The remaining three studies were diverse in their focus and suggested a protective effect of preterm birth for neuroblastoma (Johnson and Spitz, 1985), no increased risk of Hodgkin's disease in children from infectious diseases (Brubaker, 1985), and a winter predominance of births among children with acute leukemia (Meltzer et al., 1989).

Overall, these studies pertaining to childhood cancers suggest that the etiology of these diseases is not well understood. The suggestions of possible occupational and environmental associations were based on studies utilizing very crude exposure surrogates.

4.5 Occupational/Environmental Case-Control Studies of Specific Cancer Types

Twenty-six case-control studies of various cancer types were reviewed examining an occupational or environmental relationship in a non-industrial setting. These are summarized in Table 7. Most of the findings noted were selected from among numerous analyses, and were often from analyses other than ones based on a priori hypotheses. Major findings from the stronger of these case-control studies (population-based with histologic confirmation) are briefly summarized here. Divine (1978) conducted a decedent case-control study to determine if the proportion of persons dying from liver cancer (cases) were chemical workers more often than persons dying from other than malignant neoplasms. Thirty-nine residents of Brazoria County who died from liver cancer between 1960-1974 were matched to 77 controls. No associations were found between primary liver cancer and chemical industry employees; in fact, a deficit of cases was found among white males. Only 23% (9/39) of the liver cancer cases were confirmed from medical records as true primary liver cancer. The Divine (1978) study was a subset of a larger liver cancer study in Brazoria, Orange, and Jefferson Counties, Texas which examined liver cancer mortality during 1960-1972 (Buffler, 1980). Of 176 cases of liver cancer identified from death certificates during this period, only 30.6% (n=54) were confirmed by hospital and pathologic records. In the case-control component of the study based on 137 cases of primary liver cancer and 274 controls in Orange and Jefferson counties, there was no difference in occupational histories or residential patterns at time of death between cases and controls (23% of cases less than 10 kilometers from plants compared to 25% of controls).

Based on Buffler et al.'s 1984 study of respiratory cancer along the Gulf Coast, the analysis by Brown et al. (1988) included 183 white men aged 30-79 years with squamous cell carcinoma of the larynx diagnosed from 1975-1980 and 250 frequency matched population controls. Smoking and alcohol-adjusted elevated risks were detected for men employed in transportation, communication, utilities, and sanitation (OR=1.6, 95% CI=1.0-2.5), metal

Table 7

Selected Characteristics of Non-Industry Based Occupational/Environmental Case-Control Studies of Cancer in Texas

Reference	Cancer Type	Cases	Controls	Major Findings (comments)
Spitz et al., 1984	Salivary gland	498 patients M.D. Anderson 1960-81	487 other patients	Significant risk factors: previous cancer (especially skin), previous radiation
Stinnett et al., 1981	Liver	137 deaths, Orange/Jefferson Counties, 1964-76	Each death matched to two non-cancer deaths	No difference in pollution index between cases and controls. (Liver cancer unreliable from death certificates.)
Suarez et al; 1989	Liver	1,742 male deaths, Texas, 1969-80	1,742 other deaths	Significant elevated odds ratios for plumbers and pipefitters, butchers, meat cutters, textiles, oil refinery workers, cooks, but not for farm workers (No control for alcohol, chronic hepatitis.)
Divine, 1978 (Dissertation)	Liver	39 deaths, Brazoria County, 1960-75	77 other deaths	Deficit of primary liver cancer among white male chemical industry workers. Only 23% of cases were primary liver cancer as confirmed from medical records.
Buffler, 1980	Liver	137 deaths, Orange and Jefferson Counties	274 other deaths	No difference in occupational or residential patterns between cases and controls
Spitz, 1981 (Thesis)	Pancreas	312 deaths, Orange/Jefferson Counties 1965-76	619 other non-cancer deaths	Only one (Port Arthur) of 11 geographic areas was significantly elevated for pollution index. (No control for smoking, occupational exposures.)
Shellenberger, 1982 (Thesis)	Pancreas	343 male deaths Harris County 1970-74	343 other male deaths	Elevated odds ratios ($p<0.05$) noted for supervisors, marketing and sales, oil and gas extraction, mining, machinery but not for petroleum refinery industry. (No control for smoking, SES.)
Brown et al., 1988	Larynx	183 White males diagnosed 1975-80, in Six Texas Gulf Coast Counties	250 population controls	Smoking and alcohol adjusted odds ratios significant for public services, metal fabricating, construction, maintenance, diesel/gasoline fumes, paint. Significant dose response for asbestos.

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Reference	Cancer Type	Cases	Controls	Major Findings (comments)
Umphrey et al., 1984 (Thesis)	Larynx	209 White males diagnosed 1975-80 Six Texas Gulf Coast Counties	250 population controls	Same population as Brown et al., 1988. Similar findings. Also confirmed smoking and alcohol as strong risk factors. (Significantly elevated OR for chemical manufacturing in post hoc analysis.)
Wynder et al., 1973	Lung	108 women from 7 hospitals (only 1 in Texas) 1970 - 72	Matched to 4 hospital controls	Notable as one of early studies to document smoking risk for lung cancer (especially for women.)
Rom et al., 1982	Lung	575 (deaths and incident cases) (West Texas) 1944-1973	376 males with prostate cancer; 1,114 females with breast cancer	Arsenic air pollution near the El Paso non-ferrous smelter was not related to lung cancer. (Results inconclusive due to methodologic weaknesses.)
Buffler et al., 1984; Buffler et al., 1986	Lung	460 females 475 males diagnosed 1976-80 Six Texas Gulf Coast Counties	482 females 466 male population controls	Statistically elevated smoking-adjusted odds ratios detected for metals, construction, transportation and chemical industries in men; and chemical and service occupations in women.
Ives et al., 1988; Ives, 1984 (Dissertation)	Lung	259 White women diagnosed 1977-80, Harris County	278 population controls	Odds ratio for smoking and lung cancer high and significant (OR=13.9). (These results were one of first reports to note smoking risks in women comparable to men.)
Dodson et al., 1988	Lung	21 non-urban cases	10 non-urban controls	No significant difference between asbestos burden of cases and controls, but chrysotile concentrations less than urban dwellers. (Limited methodology-more of a clinical description.)
Rene, 1982 (Thesis)	Prostate	310 deaths, Harris County, 1970-74	310 other deaths	Protective odds ratio for widowed men and for service occupations. (No association for urban vs. rural residence.)
Pilon, 1981 (Thesis)	Bladder	189 deaths, Galveston/Harris Counties, 1970-78	378 other deaths	Significant odds ratios for agriculture, fishing, and forestry industries, but not for chemical or petrochemical. (No control for smoking.)
Speers et al., 1988	Brain	202 White male deaths, East Texas 1969-78	238 other deaths	Elevated odds ratios for transportation, communication, and utilities industries, and electromagnetic field exposures. (Possible confounding by concomitant chemical exposures.)
Bondy, 1982 (Thesis)	Brain	147 deaths, Galveston County, 1964-1979	294 non-cancer deaths	No association detected using 1975 EPA emission data. Elevated odds ratio for chemical manufacturing.
Lewis, 1990 (Dissertation)	Brain	375 males diagnosed 1980-84, Texas-Louisiana, Gulf Coast	450 population controls	No elevated risk of brain tumor associated with employment in electromagnetic field occupations.

Reference	Cancer Type	Cases	Controls	Major Findings (comments)
Tashjian, 1982 (Thesis)	Non-Hodgkin's Lymphoma	283 male deaths,Harris/ Galveston Counties, 1970-78	283 other deaths	Significantly elevated odds ratio for usual employment in petroleum refining industry. (Only crude odds ratios calculated.)
Crane et al., 1989	Acute Nonlymphocytic leukemia	126 adult patients, M.D. Anderson, abnormal karyotypes 1976-83	109 patients, normal karyotypes	Adjusted odds ratios elevated for prior cytotoxic therapy, cigarette smoking, alcohol use.
Crane and Keating, 1991	Acute nonlymphocytic leukemia	46 adult patients with history preleukemia phase, M.D. Anderson, 1976-83	224 acute onset leukemia patients	Elevated odds ratios for hobbies (but not occupations) with potential chemical exposure and self-reported pesticide exposure. (Conclusions limited by possible misclassification and low power.)
Godwin, 1984 (Thesis)	Acute nonlymphocytic leukemia	60 adult cases at 5 Houston hospitals, diagnosed 5/82-3/83	60 hospital based patients -nonhematologic disease	No elevated odds ratios for occupational and environmental factors. (Low power and possible selection bias.)
Huang, 1993 (Dissertation)	Leukemia (excluding chronic lymphatic)	169 males diagnosed; 1982-86 Six Texas Gulf Coast Counties	375 Population controls	Elevated odds ratios in selected jobs with high electromagnetic field exposure dependent on exposure definition.

fabricating (OR=2.1, 95% CI=1.2-3.8), construction (OR=1.7, 95% CI=1.1-2.7), and maintenance (OR=2.7, CI=1.2-5.9) occupations. A significant dose-response trend was found for level of potential asbestos exposure and laryngeal cancer. An analyses by Umphrey et al. (1984) on the same population generally reported similar findings and confirmed smoking and alcohol consumption as strong risk factors for laryngeal cancer.

Buffler et al. (1984) and Buffler et al. (1986) reported the results of an incident case-control study of occupational and lifestyle exposures and lung cancer in six Texas Gulf Coast counties with high lung cancer mortality rates. The cases consisted of 460 female and 475 male residents newly diagnosed with histologically-confirmed lung cancer from 1976-1980 and 482 female and 466 male population controls. Statistically elevated smoking-adjusted odds ratios occurred for men whose usual employment was in the following industries: metals (OR=3.4, 95% CI=1.4-8.4), construction (OR=2.6, 95% CI=1.5-4.5), transportation (OR=2.6, 95% CI=1.5-4.4), and chemical (OR=2.2, 95%CI=1.1-4.2). For women, elevated smoking-adjusted odds ratios were noted for usual employment in clerical (OR=1.6, 95% CI=1.1-2.3) and service (OR=1.6, 95% CI=1.0-2.6). Ives (1984) and Ives et al. (1988) utilized data from the Buffler et al. (1984) respiratory cancer study specifically to investigate occupation and other environmental exposures and lung cancer risk among women in Harris County, Texas. The study population included 259 white women aged 30-79 years with histologically confirmed lung cancer newly diagnosed from 1977-1980 and 278 population controls. The odds ratio for lung cancer among smokers was high and statistically significant (OR=13.9, 95% CI=7.4-26.0). The smoking-adjusted odds ratio for lung cancer among women employed in high risk industries and occupations was 1.4 (95% CI=0.8-2.4). These important results included the highest odds ratios reported at the time for smoking and lung cancer in women, comparable to high estimates in men.

In summary, the occupational/environmental case-control studies conducted in Texas were diverse in their focus, but provided some important data on risk factors for cancer. Specifically, the major findings from population-based studies, which included diagnostic confirmation, included the lack of reliability and validity of liver cancer based on death certificate diagnoses, the role of alcohol and smoking as risk factors for laryngeal cancer, the identification of high risk industries for respiratory cancer, and the major effect of smoking on lung cancer risk. The occupational contribution was relatively small compared to the smoking contribution to lung cancer in men and women. In all of these studies, better exposure assessment tools would be required to identify specific occupational carcinogens.

5.0 DISCUSSION

5.1 Summary of Occupational Risk Factors for Cancer in Texas

Overall, based on a summary of 11 non-overlapping plant populations, refinery and chemical manufacturing workers in Texas experienced a 9% deficit (statistically significant) of total cancer mortality (SMR=91, 95% CI=86-96). The deficits were most apparent for cancers of the buccal cavity/pharynx, total digestive system, esophagus, stomach, colon and rectum, liver and biliary, larynx, lung, and bladder. Two of these deficits in cancer types among workers (liver and lung) were excesses when overall Texas mortality rates were compared to the U.S. There were no statistically elevated risks overall, yet a 10% or greater excess was noted for several cancers with some statistical stability (i.e., fairly narrow confidence intervals). These included cancer of the skin (SMR=113, 95% CI=91-140), central nervous system (SMR=113, 95% CI=96-133), and three categories of the lymphohematopoietic cancer (Hodgkin's disease SMR=118, 95% CI=82-165; leukemias SMR=111, 95% CI=96-128; other lymphohematopoietic SMR=115, 95% CI=92-144). The central nervous system excess was seen primarily in the chemical manufacturing or mixed plant workers, whereas the lymphohematopoietic excess was concentrated in the refinery and mixed plant workers. It has been recognized that risks of low magnitude can more easily be explained, not only by occupational exposures, but by choice of the standard population, bias, or confounding (Wynder, 1987). However, the consistency of these low excesses and the possible dilution in exposure by considering all workers, without regard to duration or intensity of exposure argues for further consideration of these data. For skin cancer, a consistent excess could partially be explained by the predominant use of the U.S. for comparison where skin cancer mortality is 8% lower than in Texas (Miller et al., 1993), presumably due to variation in ultraviolet radiation. For brain cancer, the possibility of diagnostic sensitivity bias, i.e., differentially greater diagnosis of brain cancer as a result of more complete medical evaluation in employed compared to the general population, must also be considered (Greenwald et al., 1981). When other studies pertaining to brain cancer detected an excess, no workplace exposure or particular production area could be demonstrated to account for the excess.

From cohort studies on more specific populations or case-control studies, excess risks were suggested for lung cancer among vinyl chloride monomer workers (Buffler et al., 1979), asbestos workers (Giacco, 1985), and workers employed in metals, construction, transportation, and chemical industries (Buffler et al., 1984, 1986); prostate cancer among lubricating/dewaxing refinery workers (Ross and Enterline, 1982; Wen et al., 1985); lymphohematopoietic cancer among styrene-butadiene workers (Downs et al., 1987; Divine et al., 1990; Meinhardt et al., 1982, Lemen et al., 1990); renal cancer among chlorine production workers (Bond et al., 1985b); colorectal cancer among polypropylene workers (Acquavella et al., 1988, 1989, 1991); and childhood CNS tumors with paternal occupations involving electromagnetic field exposures (Johnson and Spitz, 1989). However, the attribution of the excess cancer to an occupational cause in these studies was weakened by inconsistency in latency and duration analyses, and non-specificity of the implicated exposure. Further, many other of the reviewed studies which

examined more specific exposure subgroups were unable to examine adequately cancer-specific risks due to very small sample size.

5.2 Summary of Non-occupational Risk Factors for Cancer in Texas

The protective effect of Vitamin A (specifically carotene) for lung and laryngeal cancer was demonstrated in several case-control studies in Texas (Bond et al., 1987; Mackerras et al., 1988; Falk et al., 1989). Familial aggregation of cancer was reported for cancers of the breast, ovary, brain (childhood), lung, prostate, and soft tissue sarcoma (Weiss et al., 1986; Bondy et al., 1991, 1992; Shaw et al., 1991, Spitz et al., 1991, Strong et al., 1992). Cigarette smoking and alcohol increased the risk for laryngeal cancer (Falk et al., 1989). The major effect of smoking on lung cancer risk was confirmed in men and women in Texas (Buffler et al., 1984, 1986; Ives et al., 1986), making it more difficult to discern any occupational causes of lung cancer.

5.3 Impact of Risk Factors on Cancer in Texas

The studies conducted in Texas clearly do not comprise the breadth of our knowledge about the etiology of cancer in this state. There is no reason to believe that what is generally known about causes of cancer would be different in Texas. However, there are variations in exposure that are different in Texas, such as the large petrochemical industry along the Gulf Coast area. The question then arises as to the relative impact of occupational and non-occupational risks on cancer in Texas. A discussion is first presented concerning the occupational and smoking contribution to the leading cause of cancer deaths, lung cancer. This is followed by a discussion of the impact of occupational and environmental exposures on the leading causes of cancer in Texas.

5.4 Occupational Attributable Risk for Lung Cancer

Lung cancer, by far, caused the greatest number of cancer deaths. A measure of the relative impact on cancer by various exposures is the population attributable risk. This measure depends not only on an established causal role but also on the known prevalence of the exposures under consideration. In the absence of either of these required data, the relative impact could not be estimated. Based on available data and informed judgment, Doll and Peto (1981) attributed 15% of male and 5% of female lung cancer to occupational exposures in the U.S. in 1978. Vineis (1988) utilized data from five case-control studies throughout the U.S. (none was in Texas) to estimate that 3 to 17% of male lung cancers were attributable to occupational causes depending on the geographic prevalence of exposures to lung carcinogens. These data suggest that occupationally-related lung cancer would be more prominent in areas of Texas with greater exposure to lung carcinogens in the workplace, but would require reliable measures of the prevalence of implicated exposures and stable risk measures which have been determined to represent causative associations. Such data are currently unavailable geographically throughout Texas. While smoking accounts for most of the associations of lung cancer and occupational exposure, even a small attributable occupational proportion would represent many deaths due to

the frequency with which lung cancer occurs. This same methodology would apply to other less frequent cancer types associated with occupational exposures.

5.5 Smoking and Lung Cancer

Smoking is most strongly related to lung cancer and has been demonstrated as such in Texas (Buffler et al., 1984; Bond, 1985; Olsen et al., in press). However, smoking has also been demonstrated to be a risk factor for numerous other cancers including oral cavity, esophagus, larynx, bladder, pancreas, leukemia, cervical, and renal cancer (Ernster, 1993; Siegel, 1993). The risks for lung cancer from smoking have also been reported to be increased among non-smokers in Texas married to smokers (Dalager et al., 1986). Lung cancer is the leading cause of cancer death in both men and women and the Centers for Disease Control and Prevention estimated that smoking accounted for 87% of lung cancer deaths in the U.S. as a whole (Boring et al., 1993).

Lung cancer mortality has increased more rapidly for women than men over the last 40 years, but the mortality rate is highly dependent on smoking patterns which have changed dramatically over time (Boring et al., 1993). Variations in lung cancer are obscured if lung cancer mortality is not examined by age-specific groups (Risser and Weiss, 1993). Based on U.S. data, smoking prevalence peaked at 67% in the 1940s and 1950s for white men born during 1911-1930. The peaks for later birth cohorts were lower and declined sharply after 1960 to 27.4% in 1991. For black men, smoking prevalence declined to 35% in 1991 and has been higher than whites since 1965. For women, smoking prevalence reached a peak of 44% for the 1931-1940 birth cohort and declined to 24% in 1991. These declines in smoking rates are reflected in the decline or leveling of lung cancer death rates for men less than 55 years and for women less than 45 years of age (Boring et al., 1993).

In Texas, a recent analysis by the Texas Department of Health highlighted the importance of examining age-specific rates and confirmed the lower lung cancer mortality among Hispanic males and females in Texas compared to Anglos, and the higher rates among black males. However, recent data showed smoking initiation rates for black males and females less than 19 years of age to be lower than Anglo males and females. If these changing patterns of smoking persist, they should be reflected in differing patterns of lung cancer mortality in several decades (Risser and Weiss, 1993).

The prevalence of smoking among teenagers has not declined appreciably since 1984 (Gritz, 1993). The targeting of teenagers, especially female adolescents in tobacco advertising has been well documented (Ernster, 1993). The teenage group is an important group on which to focus prevention efforts since 90% of smoking is initiated before the age of 20 (Ernster, 1993). A survey to determine the ability of minors to purchase cigarettes indicated that about 60% of attempts to buy cigarettes were successful in Austin, Texas despite the prohibition by law since 1989. However, if vendors asked the age of the child, no attempts were successful (Romeis et al., 1993).

Although smoking data by geographic regions in Texas would help in the interpretation of geographic differences in lung cancer, the most relevant data would be from 20 or more years ago (and are unavailable). Self-reported smoking data from the Centers for Disease Control and Prevention's Behavioral Risk Factor Surveillance data are not based on samples large enough to produce stable smoking prevalence estimates by geographic region within Texas. For example, the 1991 sample was only 1,500 for the entire state of Texas. However, from this survey, the estimated prevalence of smoking in Texas was 22% compared to 24% in the U.S. in 1991 (Texas Department of Health, 1993). As previously noted, the smoking prevalence was highly dependent on age. The proportion who reported currently smoking in Texas in 1991 ranged from 12.6% in the 65 and older age group to 26.6% in the 45-64 year age group (unpublished data, Texas Department of Health).

5.6 Inferred Impact of Occupational and Environmental Causes of Cancer in Texas

An important and fundamental question of this project was what is known about the relative contribution of environmental and occupational factors, as well as lifestyle and genetics to the burden of cancer in Texas. As previously described, to estimate reliably the impact of occupational and environmental causes of cancer in Texas, knowledge about the established causal role of the exposures for each type of cancer and the statewide prevalence of each of the implicated exposures would be required. Table 8 shows the leading causes of cancer deaths for men and women in 1992 in Texas (each category containing over 500 deaths). Among men, the three most frequent cancers (lung, prostate, colon) accounted for over half of all male cancer deaths. The addition of the three next most frequent cancers (pancreas, leukemia, non-Hodgkin's lymphoma) to the three leading causes accounted for two-thirds of all cancer deaths in men. For women, the three leading types of cancer (lung, breast, colon) accounted for nearly half of all cancer deaths and the leading seven cancer types (addition of pancreas, ovary, leukemia, non-Hodgkin's lymphoma) accounted for two-thirds of cancer deaths among women in 1991. The ranking of these leading causes of cancer deaths in Texas was identical to that of the U.S. (1986-1990); the percentages in each cancer category in Texas were generally within one percentage point of the corresponding percent in the U.S. (Miller et al., 1993).

Doll and Peto (1981), using 1978 data for the entire U.S. population, made informed estimates of the attributable proportion of occupational exposure to these cancers as follows: lung (15% of male, 5% of female cases); leukemia (10% of male, 5% of female cases); prostate (1% of male cases); and attributed a small proportion to the other causes (1% of male cases and 0.5% of female cases to cancers of the colon, pancreas, and non-Hodgkin's lymphoma). Breast and ovarian cancers were listed by Doll and Peto (1981) as ones not known to be produced by occupational hazards. For all cancers, Doll and Peto estimated between 2 to 8% of cancer in 1978 in the U.S. were due to occupational exposure and another 2% to air pollution. Even for cancer, the most extensively studied disease in relation to work, there are no sound data from which to estimate precisely the percent related to work (Rothstein et al., 1993). Many believe these estimates were reasonable for the time period in which they were estimated, and are probably still reasonable estimates of risk based on known carcinogens (Buffler et al., 1989). However, these estimates have been criticized as being too low due to the proportional approach

Table 8

Leading Types of Cancer Deaths for Men and Women in Texas
1992

	MEN		WOMEN	
CANCER TYPES	n	%	n	%
Lung/Bronchus	5635	34.9	3138	22.7
Breast	-	-	2427	17.5
Prostate	1829	11.3	-	-
Colon	1307	8.1	1342	9.7
Pancreas	739	4.6	774	5.6
Ovary	-	-	723	5.2
Leukemia	648	4.0	524	3.8
Non-Hodgkin's Lymphoma	634	3.9	516	3.7
Other Cancers	5353	33.2	4406	31.8
Total	16145	100.0	13850	100.0

Source: Cancer Registry Division, Texas Department of Health, 1993

which failed to consider the interaction between the exposures (e.g., asbestos and smoking), and to the multitude of chemicals never evaluated for carcinogenic effects (Markowitz and Landrigan, 1989) and possibly too high because 1978 mortality would reflect earlier, and likely higher levels of exposure.

There does not appear to be any more reliable alternate set of estimates. Siemiatycki (1991) employed three methods to estimate population attributable risks for 11 cancer sites. The resulting estimates varied so widely that he concluded that reasonable estimates can be made by focusing efforts on determining a more reliable and comprehensive inventory of recognized occupational carcinogens. The statistically significant excesses noted in the geographic analyses (predominantly liver and lung cancer) when comparing Texas to the U.S. were found to be statistically significant deficits in the summary SMR analyses of the cohort studies on petrochemical workers in Texas.

Some occupational and environmental exposures which have been established elsewhere as carcinogens have been documented to occur in Texas. These include arsenic and cadmium (Hubert et al., 1981), heavy metals (Landrigan and Baker, 1981; Johnson et al., 1975; Stock and Mendez, 1985), formaldehyde (Connor et al., 1985), talc (Gamble et al., 1982), and asbestos (Hurst et al., 1979) in the ambient air, and radium and radon in water (Cech et al., 1988). However, no data on the prevalence of these exposures among the residents of Texas are available now or in previous decades, when the more relevant exposures related to current cancer occurrence took place. From the critical review presented here, the data are not available to reliably estimate the relative impact of occupational and environmental exposures on these leading causes or other causes of cancer death in Texas. However, the possible excesses noted were sufficiently small that the cancer experience of refinery and chemical manufacturing workers would not make a measurable impact on cancer patterns in the entire state of Texas. This should also be expected when consideration is given to the very small proportion of the workplace which is composed of these workers. Of 7.6 million employed workers in Texas (U.S. Bureau of the Census, 1993), only 96,993 (1.3%) were employed in chemical and allied products and petroleum and coal products industries (U.S. Bureau of the Census, 1992). Even if those employed in oil and gas extraction (n=107,560) are included where the potential for exposure is considered minimal, the total proportion of these workers is still less than 3% of the Texas employed work force. While population estimates of proportional causes of cancer death are of interest, these estimates apply to an entire population, thereby obscuring potentially higher proportional attribution of various risk factors in more highly exposed subgroups. Moreover, they depend on a presumed causal relation between the risk factor and the specific cancer type. Therefore, within Texas, a more productive investment of time and resources would be to continue to reduce environmental and occupational exposures and to conduct etiologic research.

6.0 LIMITATIONS OF AVAILABLE DATA

The data that have been reviewed and presented in this report indicate that there is substantial information about cancer in Texas. These include vital statistics data pertaining to the magnitude and variation over time and across geographic areas in cancer mortality in Texas and a large number of special studies conducted in industrial and other population groups which have advanced our knowledge of various factors contributing to cancer mortality in this state.

Despite the availability of substantial information on cancer in Texas, in the process of conducting this comprehensive review, several areas were identified in which available data are limited (Specific Aim 3). These include lack of statewide cancer incidence data, certain population groups with little or no data, limited exposure information, and the incompleteness of analyses from two case-control studies on brain cancer and leukemia in Texas.

6.1 Lack of Statewide Cancer Incidence Data

For cancers with short survival, mortality serves as a reasonable surrogate for incidence. Successes in treatment for some types of cancer have dramatically affected their mortality. Monitoring cancer incidence is now considered necessary to properly evaluate prevention efforts or unsuspected increases in a specific cancer (Doll, 1991). The state cancer registry has sufficiently developed over the past several years, and reporting of cancer cases has improved that more timely population-based cancer incidence for multiple regions of the state should be available in the near future. This is a monumental surveillance activity in a state with a population of more than 17 million people and Texas should enhance its support of the cancer registry to have complete and timely state data. Cancer registries in other states have been utilized, for example, to follow-up participation in screening programs for colorectal cancer in Western New York (Michalek et al., 1988), to estimate cancer incidence among a cohort of chemical workers in California (Bond et al., 1988), to provide research collaboration, identify cancer excesses, and to plan for health care needs (Armstrong, 1992).

6.2 Population Groups with Little or No Data

Cancer mortality data cannot currently be examined by occupation and industry as coded on death certificates. These data could be used for screening purposes to identify low and high risk occupations and industries. Usual occupation and industry are recorded on death certificates, but are not coded for computerized data entry.

Although based on very small numbers, several studies in this review indicated a higher mortality for black workers compared to white workers (DeFonso and Maher, 1981; Waxweiler et al., 1983, Wen et al., 1981; 1982), although others indicated no excess (Teta et al., 1991; Olsen et al., in press). These data suggest the need to focus future research on black, Hispanic, and other minority workers. Concentrations of environmental exposures have also been reported to vary by race in Texas (Almanza et al., 1993) and further emphasize the need to conduct research on any associated health risks with these exposures in various race and ethnic groups.

In 1990, women comprised approximately 44% of the Texas work force (U.S. Bureau of the Census, 1993). Due to small numbers of women previously employed in the industrial work force, data have usually been presented for men exclusively. Little is known about occupational risks to women in Texas. Dow Chemical Company (Olsen et al., in press) included a separate analysis on 3,860 women with 86,898 person-years of observation which suggested a possible increase in lymphopoietic cancer among female workers in the Dow Chemical Company population. Future studies should also include women, when feasible.

For the period 1987-1989, the estimated number of farmworkers and family members in Texas within a given year was 281,778 migrants and dependents and 218,360 seasonal workers (who do not migrate) and dependents totaling over one-half million farmworkers and their family members. Of these, 201,085 were farm workers and 299,503 were family members who often are exposed to the same environment as the workers due to the close proximity of the farmworkers and their dependents. These numbers represented an increased overall growth of 16.3% from 1978 to 1989 (U.S. Department of Health and Human Services, 1990).

Data are scarce on cancer among migrant workers nationally (Zahm and Blair, 1993). Pesticides are one of the major exposures of concern. The few available studies among farmworkers suggested excess risks of multiple myeloma and cancer of the stomach, prostate, and testes (Zahm and Blair, 1993) and childhood cancer (Moses, 1992). At present, direct data for measuring agricultural worker exposure to pesticides within Texas are not available. Pesticide application data indicate that large acreages are being treated with highly toxic materials (Rothstein et al., 1992). With great opportunity for exposure, and substantial numbers of workers, studies of cancer and other health outcomes should be initiated in farmworkers in Texas. Methodologic difficulties in studying this population suggest the need for feasibility and descriptive studies on these populations in Texas.

6.3 Incompletness of Analyses from Brain and Leukemia Case-Control Studies

A slightly elevated, but consistent increase in brain cancer in manufacturing workers and leukemia in refinery populations was demonstrated from the studies included in this review (see Table 6). Although these risks could not be attributed to a specific job classification or exposure, the consistency strongly suggests further study. The National Cancer Institute recognized the importance of supporting research focusing on these two types of cancer in the Gulf Coast area of Texas by funding two population-based case-control studies. Dr. Patricia Buffler, formerly Professor of Epidemiology at The University of Texas-Houston School of Public Health, and currently Dean of the University of California at Berkeley School of Public Health, served as the principal investigator for these studies. Data collection and initial analyses of these two studies have been completed. A paper describing the histologic classification of brain tumors has been published (Armstrong et al., 1990), and two dissertations exploring the relationship between occupation and electric and magnetic field exposure and leukemia and brain tumor have been included in this review (Lewis, 1990; Huang, 1993). However, due to Dr. Buffler's departure, the major analyses of occupational exposures and brain tumor and leukemia incidence remain

incomplete and represent a potential for reduction in a major gap in our knowledge about these cancers in Texas.

Occupational histories collected from personal interviews with study subjects or their next of kin are available for 375 male residents of the Texas-Louisiana Gulf Coast (n=220 in Texas and 155 in Louisiana), age 20-79, with primary neuroglial central nervous system tumors diagnosed during 1980-1984 and 450 age, race, geographically matched population controls (n=257 in Texas and 193 in Louisiana). Data on sociodemographic characteristics, medical, residential, and occupational history, and exposure history to tobacco, alcohol, drugs, ionizing radiation, and other potential confounding factors were solicited by an in-person interview with the study subject or next-of-kin (Lewis, 1990).

A second case-control study (also with an occupational hypothesis) was conducted on 169 incident cases of leukemia (excluding chronic lymphatic leukemia) among male residents in the same six Texas Gulf Coast Counties diagnosed during 1982-1986 and 375 age, race, and geographically-based population controls. Information on occupational exposures, environmental exposures, cigarette smoking, medical history and personal habits was obtained via personal interview. Although a decade has elapsed since diagnosis, the time period of these studies would contribute relevant data to information available from industrial populations. These data represent an opportunity to study a series of brain cancer and leukemia cases that exceed the number in all the cohort studies combined in Table 6. Dr. Buffler and other investigators have expressed interest in continuing and completing these important and needed analyses.

6.4 Limited Exposure Information

One of the major factors in being able to associate cancer with specific exposures was the limitations in the exposure assessment, and these limitations are, therefore, discussed in depth here. The types of exposure variables developed for studies of the association of cancer with industrially-exposed, or with environmentally-exposed populations have in general different characteristics. These are based on the predominant study designs available to each type of study. In the large majority of studies, surrogates for exposure were used, rather than measures or estimates of actual exposure.

Those studies which could assemble industrial historical cohorts had options available for exposure surrogates not as available (or precise) for studies outside of industry. Such historical cohort studies reviewed for this project were usually company-supported or conducted. Also, several studies were conducted by government agencies, usually NIOSH with cooperation from the companies involved, or by labor unions which through their membership roles could assemble an essentially complete cohort related to one or a few industrial sites of similar type. Some case-control studies were conducted, usually as part of larger cohort studies.

Historical cohort studies generally used one or several of the following as exposure surrogates, in descending frequency of use and approximately increasing quality.

(a) ever/never in the plant(s) being studied (usually with a minimum time of employment varying from 1 day to 1 year);
(b) length of employment, as a surrogate for length of exposure;
(c) year of first hire;
(d) presence during periods of exposure similarity, e.g. years of batch vs. continuous production, or before/after a change in production process;
(e) qualitative job categories, such as management vs. production workers, or salaried vs. hourly, or sometimes including other categories such as maintenance or specific production job categories;
(f) ever/never exposed to certain agents or groups of agents;
(g) qualitative groupings or rankings by groups of agents, or by processes with known groupings of potential exposures;
(h) qualitative rankings (high, medium, low) for specific agents, and/or groups of agents by sub-processes with differing exposures;
(i) quantitative ranges of specific agent exposures.

These are not mutually independent. For example, year of hire tends to be related to length of employment and latency (and age), but some different information remains in each which may be a surrogate for different aspects of exposure. Also, several possible indices may represent approximately the same characteristics of exposure.

The other general category of study, in addition to historical cohort studies based in one or a few plants or companies, are those based in the general population. Two broad approaches were common. Least satisfactory are those based on an ecologic analysis. In this type of study, environmental characteristics such as average air pollution indices for an area (and frequently based on one measuring site in the area) are compared to health outcomes for the area. The areas used are typically counties, economic areas, or census tracts. These ecologic analyses all suffer from the ecologic fallacy of assuming that area characteristics apply to the individuals in them. Substantial misclassification of exposure for individuals may result, without a good estimate of the size of the error.

A second type of study possible for the general population is the case-control study, where as many cases as possible of a health outcome of interest are collected along with controls for a given period of years and a specified locale (typically a group of counties). Then past exposure characteristics of the cases and controls are obtained subsequent to diagnosis. One common approach for obtaining exposure characteristics is to note occupation and/or industry from death certificates, with all the uncertainties inherent in this technique. These include doubt whether the occupation and/or industry coded is the last one worked, the usual one, or the longest one. This issue was examined in Texas among long term (10 years or longer work duration) chemical workers by comparing work history records to death certificate designation of usual occupation and industry. Concordance ranged from 0 to 50% for the first job, to 50 to 70% for the last job, longest job, and longest job in the last 10 years of company employment. The most consistent predictor of concordance was longer job duration (Olsen et al., 1990b). In some studies,

childhood diseases have been studied for relation to parental occupation or industry as noted on the child's birth certificate (prenatal exposure) or hospital record. The latter is presumed to be occupation and industry at the time of the child's hospitalization.

A more demanding approach followed in some studies was to administer a detailed questionnaire including a detailed job history to each case and control, or closest survivor if the case was deceased. In a validation study of reported job histories at Dow Chemical's Freeport facilities, respondents recalled only 48.4% of all documented work area assignments, but only 2.6% of the chemical agents judged to be likely exposures (Bond et al., 1988). These jobs are then usually coded according to a standard classification system for occupation and industry. Typical coding systems used are the Dictionary of Occupational Titles (DOT), and the Standard Industrial Classification (SIC). Analyses can then be carried out for occurrence of meaningful combinations of these occupation and industry codes among cases or controls. It is unusual, however, to be able to analyze in greater detail than three or even the first two digits of SIC (the Major Group), or one digit of the DOT code (which specifies broad category of work). This is because of the small number of deaths from any one cause that usually fall into more highly specific categories.

In summary, exposure indices and study designs used in studies of cancer in Texas usually permitted evaluation of association of large classes of health outcomes with segments of an industry (e.g., refineries or chemical plants); at times they permitted evaluation of association of effects with specific industrial locales (e.g. one company's large multi-chemical manufacturing site); they occasionally permitted evaluation of health outcome association with specific single-product processes within large sites or as separate plants; and only infrequently they permitted association of effects with specific chemicals or even groups of chemicals, or specific processes. For most studies, the exposure indices used do not allow associations more specific than general type of plant, or perhaps at times specific process plants, to be linked with health outcomes.

7.0 CONCLUSIONS

Based on this comprehensive review of epidemiology studies on cancer in Texas, the authors have come to the following conclusions:

7.1 Aim 1: Mortality Analyses

For most cancer sites, Texas experienced a lower cancer mortality rate than the U.S. Two notable exceptions were liver and lung cancer. The consistent elevation of liver cancer mortality among all sex/race/ethnic groups (except black females) in Texas is noteworthy. Lung cancer was statistically elevated only in non-Hispanic white males and non-Hispanic white females in Texas. Overall, estimates of smoking prevalence in Texas have not exceeded that of the U.S. However, smoking is such a strong risk factor for lung cancer that a much more detailed smoking profile by age, race/ethnicity, smoking intensity, and smoking duration would be needed to rule out smoking as the major explanatory factor to this excess. Reasons for these excesses are not currently apparent from the existing literature, but deserve further consideration (see research recommendations, Section 8.0). From the summary analysis of industrial cohorts, there was a deficit of liver and lung cancer among the petrochemical workers in Texas.

The mortality analyses were performed to provide a background and perspective for the critical review of the epidemiologic studies about cancer in Texas. Such analyses are descriptive in nature and may only suggest cancers or geographic areas for further study. The rationale for comparing Texas to the U.S. is to suggest cancers, which if in excess, may suggest the presence of a Texas-specific exposure. However, if a carcinogenic exposure were ubiquitous in both Texas and the comparison population, the strategy of comparing Texas to the U.S. would not be an effective one in identifying a carcinogenic exposure. The U.S. data provide an easily available and stable comparison group for the cohort studies. However, the relative excesses and deficits in cancer mortality in Texas compared to the U.S. will effect the magnitude of the resulting SMRs when using U.S. as the comparison population.

Cancers of the lung, prostate, colon, and breast account for half of all cancer deaths in men and women in Texas. Interestingly, cancer rates in Texas were significantly lower than the U.S. for colon and rectum, breast, and prostate cancer in various race/ethnic groups. Data necessary to be able to attribute a precise proportion of these, as well as other cancers, to occupational causes are currently unavailable. Smoking is the strongest known risk factor for lung cancer, the leading cause of cancer death, yet even a small attributable occupational proportion would represent many deaths due to the frequency with which lung cancer deaths occur.

The few increasing trends in cancer mortality over recent time were primarily colon cancer (among black and Hispanic males), liver cancer among Anglo and Hispanic males, and lung cancer among Anglo females, black females, black males, and Hispanic males. There was a concentration of cancer excesses along parts of the Texas Gulf Coast, far west Texas, and in an area in south-central Texas. A geographic deficit of cancer was experienced in the

Brownsville area, areas including far west, northwest and northeast counties, and central Texas. Average annual cancer mortality rates (1986-1990) for cancers of the liver and lung were higher in Texas compared to the U.S., but reasons for this excess are not currently apparent from the literature.

7.2 Aim 2: Critical Review of Epidemiologic Literature

7.2.1 *Studies in Industrial Settings*

The aggregation of cohort studies conducted in 11 refinery and chemical manufacturing plants focused primarily on a large number of white male workers. Due to the long latency period for most cancer, the examination of these cohorts would ascertain health effects from earlier, and likely heavier exposure. Summary standardized mortality ratios (SMRs) were calculated from these studies by cancer type. Overall, there was a significant deficit in cancer mortality among petrochemical workers compared to the general U.S. population. Statistically significant deficits were also detected for nine cancer types. There were no statistically elevated SMRs; only the summary SMRs for brain cancer (primarily in chemical manufacturing workers) and leukemias (primarily in refinery workers) approached statistical significance. However, there was heterogeneity among individual SMRs which ranged from 65 to 213 for brain cancer and from 56 to 177 for leukemias. There was a significant deficit when all cancer types were examined together. The small representation of refinery and chemical workers in the Texas work force (<3%) and the small excesses of a few types of cancer indicate that the cancer excesses of these workers would not impact substantially cancer rates in Texas. However, this does not preclude a greater impact in a smaller subset of more highly exposed workers.

7.2.2 *Other Studies*

Studies conducted in other populations in Texas identified or supported associations of other, non-occupational factors with cancer. These included the protective dietary effect of Vitamin A for lung and laryngeal cancer; familial aggregation of cancers of the ovary, brain (childhood), lung, prostate, and soft tissue sarcoma; smoking and alcohol use as risk factors for laryngeal cancer; and the major effect of smoking on lung cancer.

7.3 Aim 3: Major Data Gaps

7.3.1 *Strengths and Limitations of Data Presently Available*

The epidemiologic data included in this review contributed to the identification of population rates in cancer mortality and their variation over time and within geographic areas in Texas, and to the identification of factors involved in the causation of cancer in industrial workers and other Texas populations. These critical contributions are ones only epidemiologic studies can make; however, it is also acknowledged that very low level health risks are unlikely to be detected satisfactorily by current epidemiologic methods, especially for risks related to rare

cancer types. Similarly, an excess risk of cancer may not be detectable in very small geographic areas.

The evidence about non-occupational environmental causes of cancer is very limited. For example, the environmental studies of drinking water or ambient air exposures and cancer conducted to date have used ecologic study designs and have only been suggestive of factors possibly related to cancer occurrence.

The crudeness of exposure assessment utilized in most of the studies reviewed was a major limitation in the attribution of cancer risks to specific exposures. Further limiting these conclusions about causal factors for cancer was the small sample sizes that resulted from stratifying the analyses by latency or duration of exposure intervals.

The primary focus of the cancer data presently available is on mortality. The death certificate diagnosis of cancer in relation to usual occupation and industry is a data source that has been used elsewhere as an efficient and useful screening tool to develop hypotheses regarding occupation and cancer. Currently, Texas collects, but does not code, usual occupation and industry on death certificates. However, while death certificate data are valuable for assessing the public health problem of cancer in Texas, the most satisfactory evaluation of prevention efforts, as well as the conduct of etiologic research, will depend upon the availability of long-term cancer incidence data, especially on a statewide basis.

7.3.2 *Key Unsettled Issues*

Based on the above conclusions and judgment as to essential data that may be lacking, several key issues remain unsettled. While the cancer mortality experience is generally favorable in Texas compared to the U.S., the possible reasons for the excesses in liver and lung cancer and the deficits in colorectal, prostate, and breast cancer mortality remain unresolved. In addition, trends in the frequency of cancer occurrence and the identification of various causes of cancer cannot be evaluated properly in light of the incomplete nature of cancer incidence reporting in Texas.

The data necessary to estimate the proportion of cancer attributable to specific occupational and environmental exposures (i.e., the known prevalence of exposures and established causal relationship of exposures to cancer) are essentially lacking in Texas, as in most other defined geographic areas. In addressing an analogous question for the entire U.S. population in 1978, Doll and Peto (1981) used informed judgment to estimate that only about 6% of cancer deaths could be attributed to specific occupational and environmental exposures, while 30% could be attributed to smoking, 35% to diet, 10% to infection, 7% to reproductive and sexual behavior, 3% to alcohol, and 9% to other causes. Whether or not these estimates accurately reflect the experience in Texas is presently unknown. If so, these exposures could be important insofar as they are controllable, because to a commensurate degree, the associated cancers are preventable.

Further, the risks associated with occupational or environmental exposures may be higher in certain subgroups of the population. For example, little or no data are available on occupational or environmental risks for cancer in blacks, Hispanics, women, and farmworkers.

The risks for brain cancer and leukemias among petrochemical workers in Texas were slightly elevated. The possible occupational contribution to these cancers remains unsettled.

7.4 Other Considerations in Relation to Cancer in Texas

Beyond the information reviewed in this report, which emphasizes environmental and occupational factors in relation to cancer, a number of other considerations should be noted to put the entire framework of cancer control and prevention in perspective. These include screening programs for cancer in Texas, and preventive measures that can be implemented without further knowledge.

While review of cancer prevention policies and practices is beyond the scope of this report, implementation of preventive measures would also be expected to benefit the population of Texas. Texas women are screened less than U.S. women for cervical cancer (Weiss, 1991). A Texas Department of Health analysis showed that black and Hispanic women were diagnosed at later stages when both breast and cervical cancers were detected. Community-based interventions are currently ongoing to increase screening for breast and cervical cancer in Hispanic women in the Coastal Bend area of Texas and among black women in the Houston-Galveston area (Suarez et al., 1991).

Information is sufficient currently to vigorously support smoking prevention and cessation programs. Such programs include school-based health education programs, reducing accessibility of minors to tobacco, and implementation of restrictive advertising and smoking policies. The Centers for Disease Control and Prevention also recommends reduced alcohol use and increased consumption of fruits and vegetables to further prevent cancer (Boring et al., 1993).

8.0 RECOMMENDATIONS FOR FUTURE RESEARCH

Based on available studies on cancer in Texas, the overall contribution from the petrochemical industry to cancer mortality in Texas appears to be slight; however, continued study of more highly exposed subgroups, and continuation and initiation of cohort studies are appropriate. The available published occupational data do not usually permit evaluation of cancer risk of workers other than white males, and studies of other groups and in other industries are needed. Further, a confident statement regarding an environmental contribution to cancer in Texas cannot be made with the evidence currently available.

The public health efforts needed to improve cancer control and prevention in Texas should not be held in abeyance while further information is obtained. These include smoking prevention and cessation programs, cancer screening, and reduction in controllable environmental and occupational exposures. Yet, based on the key unresolved issues discussed in the previous section and the emphasis of this report on environmental and occupational risk factors for cancer, the following recommendations are made for further research. The first three involve support of activities through the Texas Department of Health; the remaining involve research, education, and cancer control projects.

(1) ***Expand and enhance cancer incidence reporting in Texas by the Cancer Registry Division, Texas Department of Health, with the goal of statewide coverage and complete and timely reporting.***

While mortality data continue to be useful for detecting cancer excesses and monitoring time trends for many cancers, cancer control efforts in Texas are hampered by incomplete cancer incidence data. For cancers with long survival, and for cancers with effective treatments, cancer mortality will not continue to serve as an adequate substitute for incidence. Further, additional advantages of state cancer incidence data include the ability to calculate background incidence rates for the numerous cancer cluster investigations, to which the Texas Department of Health must respond; the availability of data on histologic type of cancers; the ability to identify low and high risk areas for further study; the opportunity to utilize data to plan for adequate services for the diagnosis, treatment, and rehabilitation of cancer patients (Parkin et al., 1985), and to serve as a resource to evaluate effects of early diagnosis and treatment of cancer or the removal of implicated exposures (environmental, occupational, or lifestyle); the opportunity to serve as a source for follow-up of cancer endpoints for epidemiologic cohort studies; and for verification of completeness of ascertainment for epidemiologic-based case-control studies.

The small, but dedicated staff of the Cancer Registry Division in Texas is woefully inadequate to meet the needs of a model cancer registry. Although the current registry responds to numerous requests for cancer cluster investigations, has increased the number of institutions complying with the cancer reporting law (approximately 95% of hospitals have submitted at least one cancer case in the last 13 months), and abstracts, processes, and analyzes reports of cancer, additional resources are needed. Five regions of the state currently have population-based incidence data for certain years. Reaching complete reporting for the state will require additional

resources. The cancer registry has applied for federal funding to expand and enhance their data collection efforts.

(2) Expand and refine the cancer mortality analyses presented in this report.

Current statistical reporting of mortality data by the Texas Department of Health should be continued. The mortality analyses included in this report were based on data provided by the Cancer Registry Division. Additional analyses are recommended. These include age-specific analyses for lung cancer mortality, especially in areas where there is an apparent excess. Time trends should be examined over a longer period of time incorporating three-year moving averages to gain stability in the rates. To examine cancer possibly associated with occupational causes, the age range could be restricted to 35 to 64 years of age. Further, a common method to identify Hispanics for both deaths and population estimates should be incorporated in future analyses. Finally, the cancer sites included in this report represent approximately 80% of all cancer deaths. Other types of cancer, not included in this report, should be examined.

(3) Code death certificate information on usual occupation and industry and enter into the computerized mortality files.

The death certificate diagnosis of cancer in relation to usual occupation and industry is a data source that has been used elsewhere as a screening tool to examine possible high risk occupations and industries (Burnett et al., 1994). Currently, Texas collects, but does not code usual occupation and industry from the death certificate. These data would be useful because they cover the entire work force, can be analyzed on an individual level, are accessible and familiar to researchers, and are available within a relatively short period of time (Rothstein et al., 1993). To further enhance surveillance and research efforts, a short occupational questionnaire could be sent by the Texas Department of Health to family members of a subset of decedents who died due to selected causes of death.

(4) Update periodically industry-based cohort mortality studies to monitor trends in cancer risk and to increase the sample size of the studies. Initiate cohort incidence studies.

There have been numerous cohort mortality studies conducted on refinery and chemical manufacturing workers in Texas. However, only four (9.3%) of the 43 cohort studies included in this review have followed the cohort through the 1980s. It is important to continue to monitor these cohorts for cancers in which excesses were noted, for cancer mortality which may reflect changes in industrial processes, and for cancer mortality as the cohorts continue to age. Further, complete statewide cancer incidence reporting would allow the matching of workers in these cohorts to cancer registry data to implement cohort incidence studies. These could then be updated efficiently on a regular basis.

(5) Continue and expand occupational epidemiologic studies in previously understudied working populations.

There are few data available regarding cancer risks in industrial populations among workers who are black, Hispanic, or female, and among migrant and seasonal farmworkers. Currently, constrained by small numbers, epidemiologic methods are not sufficiently sensitive to be able to identify small cancer risks reliably in these populations. However, databases should be established or expanded for future studies. With opportunity for exposure, and substantial numbers of workers, studies of cancer should be initiated among farmworkers in Texas.

(6) Continue research regarding occupational factors contributing to brain cancer and leukemia.

The summary analysis across 11 plant populations in Texas revealed a small excess in brain cancer and leukemia. At the minimum, existing data (as described in Section 6.3), should be exploited by completing and publishing analyses on two population-based case-control studies on brain cancer and leukemia conducted in the Gulf Coast area of Texas. Since these data represent cases diagnosed in the early and mid-1980s, it would also be desirable to update these studies.

To enhance the exposure component of the brain cancer study, the investigators could incorporate the job exposure matrices developed by the National Cancer Institute (Heineman et al., in press) which was developed to examine the association of six specific chlorinated aliphatic hydrocarbons with brain cancer mortality in workers in southern Louisiana, northern New Jersey and Philadelphia, Pennsylvania.

(7) Investigate factors influencing the excess of liver and lung cancer mortality and the deficit of colorectal cancer, prostate, and breast cancer mortality.

The excesses in liver cancer and lung cancer mortality in Texas compared to the U.S. were not apparent in the cohort studies of petrochemical workers. Liver cancer is a complex disease composed of various cell types with different etiologies. The strongest risk factor for the most common type of liver cancer, hepatocellular carcinoma, is chronic Hepatitis B infection (Beasley, 1988). Further, the misclassification of liver cancer as ascertained by death certificates in Texas is substantial; therefore, careful investigations of populations in Texas need to incorporate incidence data with histologic confirmation. The San Antonio region of Texas would be an efficient area in which to examine possible reasons for increased liver cancer, as this region was identified most frequently to be in excess for this cancer by the geographic analyses and the cancer registry already has complete incidence reporting in that area. Although there was a deficit of liver cancer in the summary analysis of petrochemical workers, a previous decedent case-control study of liver cancer and occupation (ascertained from death certificates) in Texas identified several other occupations which may be at higher risk (Suarez et al., 1989). This study should be repeated in a defined Texas population in which accurate classification of hepatocellular liver cancer can be assured and important confounders can be controlled.

The major effect of smoking in the development of lung cancer makes the investigation of other risk factors very difficult. Excess risks associated with non-smoking risk factors are important to identify because, even if proportionally small, these may affect large numbers of people due to the frequency with which lung cancer occurs. In the future, if smoking prevalence continues to decline, it may become methodologically easier to discern environmental and occupational risk factors for lung cancer. While Doll and Peto (1981) recommended a national study composed of 10,000 cases to examine occupational and non-occupational risk factors in the development of lung cancer, this is not a feasible recommendation for a single state to implement. Since various sex/race/ethnic groups along several areas of the Gulf Coast experienced greater than expected numbers of lung cancer deaths compared to the experience of the entire state, epidemiologic investigations of possible effects of environmental exposures along the Gulf Coast area are recommended (see recommendation 8).

Texas experienced significantly lower levels of colorectal cancer, prostate, and breast cancer mortality in various race/ethnic groups compared to the U.S. Prostate and breast cancer are the second leading causes of cancer deaths in men and women, respectively; colorectal cancer is the third leading cause of cancer deaths in both men and women. The reasons for the significantly lower rates should be explored to attempt to understand if there are differences in the prevalence of risk factors or differences in detection of these cancers in Texas.

*(8) **Initiate studies of environmental exposures and cancer in Texas.***

To further our knowledge about environmental exposures and cancer, these studies should advance to utilizing analytic epidemiologic study designs and not only the ecologic one. The limitation in available scientifically rigorous environmental epidemiologic studies is not unique to Texas. There are many difficulties in characterizing exposures of communities over an extended period of time, in detecting low to moderate levels of risk, and in accounting for population migration. Working populations are efficient ones in which to study health effects from chemical exposures because workers are likely to experience higher exposure than the general population, and the population at risk (necessary in computing rates) is more easily defined. However, in light of the generally low cancer mortality experience among petrochemical workers in the upper Gulf Coast area of Texas, the Gulf Coast excess in various cancers and in various sex/race/ethnic groups supports the need to study possible environmental factors which may contribute to the excess. For example, recent studies conducted outside of Texas have indicated increased total mortality and lung cancer mortality associated with fine particulate air pollution after controlling for smoking (Dockery et al., 1993). Carefully conducted studies of air pollution and cancer should be undertaken in Texas incorporating refined measures of exposure, sources of pollution, and individual control for potential confounding factors, such as smoking.

(9) ***Incorporate industrial hygiene measurements and sampling for biologic exposure indices (ACGIH, 1993), when feasible, into future epidemiologic research to improve the exposure assessment component in future epidemiologic studies and to improve the ability to detect exposure-outcome associations.***

The chemical-specific historical cohort mortality studies often used available industrial hygiene data to develop job exposure matrices. Current industrial hygiene practices will likely provide more industrial hygiene data for future studies; however, personal monitoring data over time using consistent and recorded objectives and sampling strategies have been rarely collected. An increase in precision of the exposure assessment would reduce problems in misclassification inherent in the current use of surrogates of exposure such as job title.

(10) ***Describe smoking profiles for Texas.***

Currently, data from the Centers for Disease Control and Prevention's Behavioral Risk Factors Surveillance System are based on a sample too small to provide stable smoking prevalence estimates when stratified by demographic variables or geographic areas. For example, the 1991 survey data were based on a sample of only 1,500 respondents. The data should be further analyzed by accumulating across years and/or the sample increased to provide more reliable data. The data would be useful in interpreting future patterns of smoking-related cancers.

(11) ***Educate the public about what is known and what is unknown about cancer, its causes and its prevention.***

The main focus of this report was to critically review the epidemiologic studies on cancer in Texas, necessarily involving scientific language and concepts, with the intention to ultimately publish this review in the peer-reviewed scientific literature. However, information on cancer should be disseminated to the public. Educational courses (community and academically-based) and media-based reports pertaining to cancer, its causes and its prevention, should be used to disseminate this information. Further, scientific methods (cancer cluster investigations, epidemiologic, clinical, and toxicologic studies) and their strengths and limitations should be conveyed in terms that the public can understand.

BIBLIOGRAPHY

ACGIH (1993): 1993-1994 Threshold Limit Values and Biological Exposure Indices. American Conference of Governmental Industrial Hygienists, Cincinnati, OH, 124+vi. pages.

*Achterberg J, Collerrain I, Craig P (1978): A possible relationship between cancer, mental retardation and mental disorders. Soc Sci Med; 12:135-139.

*Acquavella JF, Douglass TS, Phillips SC (1988): Evaluation of excess colorectal cancer incidence among workers involved in the manufacture of polypropylene. J Occup Med 30:438-442.

*Acquavella JF, Douglass TS, Vernon S, Hughes JI, Thar WE (1989): Assessment of colorectal cancer screening outcomes among workers involved in polypropylene manufacture. J Occup Med 31:785-791.

*Acquavella JF, Owen CV (1990): Assessment of colorectal cancer incidence among polypropylene pilot plant employees. J Occup Med 32:127-130.

*Acquavella JF, Owen CV, Bird MG, Yarborough CM, Lynch J (1991): An adenomatous polyp case-control study to assess occupational risk factors following a workplace colorectal cancer cluster. Am J Epidemiol 133:357-367.

*Agu VU, Christensen BL, Buffler PA (1980): Geographic patterns of multiple myeloma: racial and industrial correlates, state of Texas, 1969-71. JNCI 65:735-738.

Alamanza SR, Diaz A, Kelly ME, Sanger M (1993): Toxics in Texas and their Impact on Communities of Color. Austin: Texas Center for Policy Studies.

Alderson MR, Rattan NS (1980): Mortality of workers on an isopropyl alcohol plant and two MEK dewaxing plants. Br J Ind Med 37:85-89.

*Aldrich TE (1985): Employment and exposures in the petroleum refining and petrochemical industries and the risk of lung cancer. University of Texas School of Public Health Dissertation T01660.

*Alexander V, Leffingwell SS, Lloyd JW, Waxweiler RJ, Miller RL (1980): Brain cancer in petrochemical workers: a case series report. Am J Ind Med 1:115-123.

*Alexander V, Leffingwell SS, Lloyd JW, Waxweiler RJ, Miller RL (1982): Investigation of an apparent increased prevalence of brain tumors in a US petrochemical plant. Ann N Y Acad Sci 381:97-107.

Armstrong BK. The role of the cancer registry in cancer control (1992): Cancer Causes Control 3:569-579.

Armstrong DD, Almes MJ, Buffler P, Frankowski R, McGarry P (1990): A cluster classification for histologic diagnoses of CNS tumors in an epidemiology study. Neuroepidemiology 9:2-16.

Austin H, Delzell E, Cole P (1988): Benzene and leukemia. A review of the literature and a risk assessment. Am J Epidemiol 127:419-439.

*Austin SG, Schnatter AR (1983b): A case-control study of chemical exposures and brain tumors in petrochemical workers. J Occup Med 25:313-320.

*Austin SG, Schnatter AR (1983a): A cohort mortality study of petrochemical workers. J Occup Med 25:304-312.

Beasley RP (1988): Hepatitis B Virus. The major etiology of hepatocellular carcinoma. Cancer 61:1942-1956.

*Blair SN, Kohl III HW, Paffenbarger RS, Clark DG, Cooper KH, Gibbons LW (1989): Physical fitness and all-cause mortality a prospective study of healthy men and women. JAMA 262:2395-2401.

*Bogdan GF (1982): Assessment of the relation of cancer mortality rates and sources of drinking water in Texas. University of Texas School of Public Health Dissertation T01276.

*Bond GG (1985): Determinants of lung cancer among chemical workers. Ph.D. Dissertation. Ann Arbor, MI: University Microfilms, International.

Bond GG, Austin DF, Gondek MR, Chiang M, Cook RR (1988): Use of a population-based tumor registry to estimate cancer incidence among a cohort of chemical workers. J Occup Med 30:443-448.

*Bond GG, Bodner KM, Olsen GW, Cook RR (1992): Mortality among workers engaged in the development or manufacture of styrene-based products-an update. Scand J Work Environ Health. 18:145-154.

Bond GG, Bodner KM, Sobel W, Shellenberger RJ, Flores GH (1988): Validation of work histories obtained from interviews. Am J Epidemiol 128:343-351.

*Bond GG, Cook RR, Shellenberger RJ, Daniel RL, Fishbeck WA (1982): Case-control study of brain tumor deaths among employees at a chemical manufacturing plant. Ann N Y Acad Sci 381:73-82.

*Bond GG, Cook RR, Wight PC, Flores GH (1983): A case-control study of brain tumor mortality at a Texas chemical plant. J Occup Med 25:377-386.

*Bond GG, Flores GH, Shellenberger RJ, Cartmill JB, Fishbeck WA, Cook RR (1986): Nested case-control study of lung cancer among chemical workers. Am J Epidemiol 124:53-66.

*Bond GG, Flores GH, Stafford BA, Olsen GW (1991): Lung cancer and hydrogen chloride exposure: results from a nested case-control study of chemical workers. J Occup Med 33:958-961.

*Bond GG, Reeve GR, Ott MG, Waxweiler RJ (1985a): Mortality among a sample of chemical company employees. Am J Ind Med 7:109-121.

*Bond GG, Shellenberger RJ, Fishbeck WA, Cartmill JB, Lasich BJ, Wymer KT, Cook RR (1985b): Mortality among a large cohort of chemical manufacturing employees. JNCI 75:859-869.

*Bond GG, Shellenberger RJ, Flores GH, Cook RR, Fishbeck WA (1985c): A case-control study of renal cancer at a Texas chemical plant. Am J Ind Med 7:123-139.

*Bond GG, Thompson FE, Cook RR (1987): Dietary vitamin A and lung cancer: results of a case-control study among chemical workers. Nutr Cancer 9:109-121.

*Bondy ML (1982): Evaluation of the association of environmental pollutants and central nervous system cancer mortality in high risk geographic area. University of Texas School of Public Health Thesis T01208.

*Bondy ML, Lustbader ED, Buffler PA, Schull WJ, Hardy RJ, Strong LC (1991): Genetic epidemiology of childhood brain tumors. Genet Epidemiol 8:253-267.

*Bondy ML, Spitz MR, Halabi S, Fueger JJ, Vogel VG (1992): Low incidence of familial breast cancer among Hispanic women. Cancer Causes Control 3:377-382.

Boring CC, Squires TS, Tong T, Heath CW (1993): Mortality trends for selected smoking-related cancers and breast cancer--U.S., 1950-1990. MMWR 44:857,863-866.

Bornstein FP (1970): Gallbladder carcinoma in the Mexican population of the Southwestern United States. Path Microbiol 35:189-191.

*Brown LM, Mason TJ, Pickle LW, Stewart PA, Buffler PA, Burau K, Ziegler RG, Fraumeni JF (1988): Occupational risk factors for laryngeal cancer on the Texas gulf coast. Cancer Res 48:1960-1964.

*Brubaker T (1985): Case-control study of childhood Hodgkin's disease. University of Texas School of Public Health Thesis T01629.

Buffler PA (1978): Statistical and epidemiologic considerations in evaluation of environmental cancer. In Bean WB (ed). Environmental cancer: a report to the public. Tex Rep Biol Med 37:64-93.

*Buffler PA (1980): Epidemiology of primary liver cancer in selected Texas counties. Final Report NCI Contract #NO1 CP 91037.

*Buffler PA, Contant CF, Pickle LW, Burau K, Cooper SP, Mason TJ (1986): Environmental associations with lung cancer in Texas coastal counties. In Clinical Conference on Cancer, Series #28, Lung Cancer: Current Status and Prospects for the Future. C.F. Mountain, D.T. Carr (eds). Austin: University of Texas Press, pp. 27-34.

Buffler PA, Cooper SP, Delclos GD, Key MM. Feasibility workshop: the problem of chronic disease in the workplace. Unpublished summary report, 1989.

*Buffler PA, Cooper SP, Stinnett S, Contant C, Shirts S, Hardy RJ, Agu V, Gehan B, Burau K (1988): Air pollution and lung cancer mortality in Harris County, Texas, 1979-1981. Am J Epidemiol 128:683-699.

*Buffler PA, Pickle LW, Mason TJ, Contant C (1984): The causes of lung cancer in Texas. Lung Cancer Causes and Prevention, Verlag Chemie International, Inc. pp. 83-99.

*Buffler PA, Wood S, Eifler C, Suarez L, Kilian DJ (1979): Mortality experience of workers in a vinyl chloride monomer production plant. J Occup Med 21:195-203.

*Buffler PA, Wood SM, Suarez L, Kilian DJ (1978): Mortality follow-up of workers exposed to 1,4-dioxane. J Occup Med 20:255-259.

Burnett CA, Silverman DT, Lalich NR (1994): A comparison of analyses of occupational bladder cancer: death certificate vs. population-based case-control interview data. Am J Ind Med 25:677-688.

Cancer Registry Division, Texas Department of Health (1993): Texas Cancer Mortality Statistics for 1992.

*Carlo GL , Jablinske MR, Lee NL, Sund KG, Corn M (1993): Reduced mortality among workers at a rubber plant. J Occup Med 35:611-616.

*Cech I, Holguin AH, Littell AS, Henry JP, O'Connell J (1987): Health significance of chlorination byproducts in drinking water: the Houston experience. Int J Epidemiol 16:198-207.

*Cech I, Holguin A, Sokolow H, Smith V (1984): Selenium availability in Texas: possible clinical significance. South Med J 77:1415-1420.

Cech I, Lemma M, Kreitler CW, Prichard HM (1988): Radium and radon in water supplies from the Texas Gulf Coastal Aquifer. Water Res 22:109-121.

Connor TH, Theiss JC, Hanna HA, Monteith DK, Matney TS (1985): Genotoxicity of organic chemicals frequently found in the air of mobile homes. Toxicol Lett 25:33-40.

*Crane MM, Keating MJ (1991): Exposure histories in acute nonlymphocytic leukemia patients with a prior preleukemic condition. Cancer 67:2211-2214.

*Crane MM, Keating MJ, Trujilo JM, Labarthe DR, Frankowski RF (1989): Environmental exposures in cytogenetically defined subsets of acute nonlymphocytic leukemia. JAMA 262:634-639.

Dalager NA, Pickle LW, Mason TJ, Correa P, Fontham E. Stemhagan A, Buffler PA, Ziegler RG, Fraumeni JF (1986): The relation of passive smoking to lung cancer. Cancer Res 46:4808-4811.

*DeFonso LR (1977): Texas plant mortality study (1948-1976). Company Report.

*DeFonso LR, Maher KV (1981): Texas plant mortality study (1948-1978). Company Report.

DerSimonian R, Laird N (1986): Meta-analysis in clinical trials. Controlled Clin Trials 7:177-188.

*Divine BJ (1978): Primary liver cancer and occupation Brazoria County, Texas. University of Texas School of Public Health Dissertation T00729.

Divine BJ (1980): Another view (letter). J Occup Med 2:640.

*Divine BJ (1990): An update on mortality among workers at a 1,3-butadiene facility-preliminary results. Environ Health Perspect 86:119-128.

*Divine BJ, Barron V (1986): Texaco mortality study: II. patterns of mortality among white males by specific job groups. Am J Ind Med 10:371-381.

*Divine BJ, Barron V (1987): Texaco mortality study: III. a cohort study of producing and pipeline workers. Am J Ind Med 11:189-202.

*Divine BJ, Barron V, Kaplan SD (1985): Texaco mortality study: I. mortality among refinery, petrochemical, and research workers. J Occup Med 27:445-447.

Dockery DW, Pope CA, Xu X, Spengler JD, Ware JH, Fay ME, Ferris BG, Speizer FE (1993): An association between air pollution and mortality in six U.S. cities. N Engl J Med 329:1753-1759.

*Dodson RF, Williams MG, Corn CJ, Rankin TL (1988): A comparison of asbestos burden in non-urban patients with and without lung cancer. Cytobios 56:7-15.

Doll R (1991): Progress against cancer: an epidemiologic assessment. Am J Epidemiol 134: 675-688.

Doll R, Peto R (1981): The causes of cancer: quantitative estimates of avoidable risks of cancer in the United States today. JNCI 66:1193-1265.

Dougherty J (1990): Polypropylene and colorectal adenomas: searching for prevalence (letter). J Occup Med 32:1141-1142.

*Downs TD, Crane MM, Kim KW (1987): Mortality among workers at a butadiene facility. Am J Ind Med 12:311-329.

*Eccleston R (1978): Descriptive study of mortality from gastrointestinal and urinary cancer in Houston with reference to sources of drinking water. University of Texas School of Public Health Thesis T00737.

*Enterline PE, Henderson V, Marsh G (1990): Mortality of workers potentially exposed to epichlorohydrin. Br J Ind Med 47:269-276.

Ernster VL (1993): Women and smoking. Am J Public Health 83:1202-1203.

*Falk RT, Pickel LW, Brown LM, Mason TJ, Buffler PA, Fraumeni JF (1989): Effect of smoking and alcohol consumption on laryngeal cancer risk in coastal Texas. Cancer Res 49:4024-4029.

Fleiss JL, Gross AJ (1991): Meta-analysis in epidemiology, with special reference to studies of the association between exposure to environmental tobacco smoke and lung cancer: a critique. J Clin Epidemiol 44:127-139.

*French JA (1982): Assessment of aflatoxin B_1, and other selected variables, in a rural environment and associated cancer risk. University of Texas School of Public Health Dissertation T01282.

Gamble J, Greife A, Hancock J (1982): An epidemiological-industrial hygiene study of talc workers. Ann Occup Hyg 26:1-4.

*Giacco GG (1985): Lung cancer mortality experience in a cohort of workers exposed to amosite asbestos. University of Texas School of Public Health Thesis T01582.

Gibbs GW (1990): Colorectal cancer and polypropylene exposure: How good is the evidence? J Occup Med 32:1143.

*Godwin J (1984): Case comparison study of occupational and environmental exposures and the risk of developing acute nonlymphocytic leukemia in adults. University of Texas School of Public Health Thesis T01529.

Greenwald P, Friedlander BR, Lawrence CE, Hearn T, Earle K (1981): Diagnostic sensitivity bias--an epidemiologic explanation for an apparent brain tumor excess. J Occup Med 23:690-694.

*Grimardi S, Johnson P, Perlman G, Wamester B, Wypijewski C (1989): Mortality patterns in the vicinity of Union Carbide chemical plants. Yale MPH students. (Unpublished Report)

Gritz ER (1993): Lung cancer: now more than ever, a feminist issue. CA 43:197-199.

*Hanis NM, Shallenberger LG, Donaleski DL, Sales EA (1985b): A retrospective mortality study of workers in three major U.S. refineries and chemical plants. Part II: internal comparisons by geographic site, occupation, and smoking history. J Occup Med 27:361-369.

*Hanis NM, Shallenberger LG, Donaleski DL, Sales EA (1985a): A retrospective mortality study of workers in three major U.S. refineries and chemical plants. Part 1: comparisons with U.S. population. J Occup Med 27:283-291.

*Haring MK (1983): Report of the NIOSH reanalysis of a retrospective cohort mortality study of petrochemical workers in Deer Park, Texas. Company Report.

Heineman EF, Cocco P, Gomez MR, Dosemeci M, Stewart PA, Hayes RB, Zahm SH, Thomas TL, Blair A. Occupational exposure to chlorinated aliphatic hydrocarbons and risk of astrocytic brain cancer. In press, Am J Ind Med.

*Henry JP (1982): Relation of selected cancer mortality rates to water source: Houston, Texas, 1940-1974. University of Texas School of Public Health Thesis T01228.

*Holck SE, Warren CW, Rochat RW, Smith JC (1982): Lung cancer mortality and smoking habits: Mexican-American women. Am J Public Health 72:38-42.

*Hollingsworth JA (1982): A descriptive study of geographic variation of cancer mortality in Texas cities in relation to source of water. University of Texas School of Public Health Thesis T01229.

*Hoover R, Fraumeni JF (1975): Cancer mortality in U.S. counties with chemical industries. Environ Res 9:196-207.

*Huang B (1993): Leukemia and occupational exposure to electromagnetic fields: an incident case-control study. University of Texas School of Public Health Dissertation T02615.

Hubert JS, Candelaria RM, Rosenblum B, Munoz R (1981): A survey of ambient air levels of arsenic and cadmium in El Paso, Texas from 1972-1979. J Air Pollution Control Assoc 31:261-262.

Hurst GA, Spivey CG, Matlage WT, Miller JM, Faulk G, Hieger LR, McLarty JW, Greenberg SD (1979): The Tyler asbestos workers program. I. A Medical surveillance model and method. Arch Environ Health 34:432-439.

*Ives JC (1984): Environmental exposures and lung cancer risk among women in Harris County, Texas (1977-1980). University of Texas School of Public Health Dissertation T01504.

*Ives JC, Buffler PA, Selwyn BJ, Hardy RJ, Decker M (1988): Lung Cancer mortality among women employed in high-risk industries and occupations in Harris County, Texas 1977-1980. Am J Epidemiol 127:65-74.

*Johnson CC (1985): An epidemiologic case-control analysis of childhood intracranial and spinal cord tumors in relation to parental occupation at birth. University of Texas School of Public Health Dissertation T01620.

*Johnson CC, Annegers JF, Frankowski RF, Spitz MR, Buffler PA (1987): Childhood nervous system tumors-an evaluation of the association with paternal occupational exposure to hydrocarbons. Am J Epidemiol 126:605-613.

*Johnson CC, Spitz MR (1985): Neuroblastoma: case-control analysis of birth characteristics. JNCI 74:789-792.

*Johnson CC, Spitz MR (1989): Childhood nervous system tumours: an assessment of risk associated with paternal occupations involving use, repair, or manufacture of electrical and electronic equipment. Int J Epidemiol 18:756-762.

Johnson DE, Tillery JB, Prevost RJ (1975). Trace metals in occupationally and nonoccupationally exposed individuals. Environ Health Perspect 10:151-158.

*Joyner RE (1964): Chronic toxicity of ethylene oxide. A study of human responses to long-term low-level exposures. Arch Environ Health 8:700-710.

*Khalfan SA (1985): Lung cancer among Texas male oil refinery workers (1976-1980). University of Texas School of Public Health Dissertation T01658.

Landrigan PJ, Baker EL (1981): Exposure of children to heavy metals from smelters: epidemiology and toxic consequences. Environ Res 25:204-224.

Lee ES, Roberts RE, Labarthe DR (1976): Excess and deficit lung cancer mortality in three ethnic groups in Texas. Cancer 38:2551-2556.

*Leffingwell SS, Waxweiler R, Alexander V, Ludwig HR, Halperin W (1983): Case-control study of gliomas of the brain among workers employed by a Texas City, Texas chemical plant. Neuroepidemiology 2:179-195.

*Lemen RA, Meinhardt TJ, Crandall MS, Fajen JM, Brown DP (1990): Environmental epidemiologic investigations in the styrene-butadiene rubber production industry. Environ Health Perspect 86:103-106.

*Lewinsohn HC, Ott MG (1991): A review of medical surveillance records of employees exposed to ethyleneamines. J Occup Med 33:148-154.

*Lewis RJ (1990): A case-comparison interview study of brain tumors and employment in occupations with presumed electric and magnetic field exposures. University of Texas School of Public Health Dissertation T02266.

Lewis RJ, Lerman SE, Schnatter AR, Hughes JI, Vernon SW (1994): Colorectal polyp incidence among polypropylene manufacturing workers. J Occup Med 36:174-181.

*Macdonald EJ (1976a): Demographic variation in cancer in relation to industrial and environmental influence. Environ Health Perspect 17:153-166.

Macdonald EJ (1976b): Air pollution, demography, cancer: Houston, Texas. JAMWA 31:379-395.

*Mackerras D, Buffler PA, Randall DE, Nichaman MZ, Pickle LW, Mason TJ (1988): Carotene intake and the risk of laryngeal cancer in coastal Texas. Am J Epidemiol 128:980-988.

Markowitz S, Landrigan P (1989): Occupational disease in New Jersey. Report to the New Jersey Department of Health. December.

*Marmor M (1978): Air pollution and cancer in Houston, Texas a causal relationship? JAMWA 33:275-277.

*Marsh GM, Enterline PE, McCraw D (1991): Mortality patterns among petroleum refinery and chemical plant workers. Am J Ind Med 19:29-42.

Martin J, Suarez L (1987): Cancer mortality among Mexican Americans and other whites in Texas, 1969-1980. Am J Public Health 77:851-853.

*Matanoski GM, Stockwell HG, Diamond EL, Haring-Sweeney M, Joffee RD, Mele LM, Johnson ML (1986): A cohort mortality study of painters and allied tradesmen. Scand J Work Environ Health 12:16-21.

*Meinhardt TJ, Lemen RA, Crandall MS, Young RJ (1982): Environmental epidemiologic investigation of the styrene-butadiene rubber industry. Mortality patterns with discussion of the hematopoietic and lymphatic malignancies. Scand J Work Environ Health 8:250-259.

*Meltzer AA, Spitz MR, Johnson CC, Culbert SJ (1989): Season-of-birth and acute leukemia of infancy. Chronobiol Int 6:285-289.

Michalek AM, Cummings KM, Gamble D (1988): The use of a cancer registry in a mass screening program for colorectal cancer. Cancer Detect Prev 11:353-357.

Miller BA, Ries LAG, Hankey BF, Kosary CL, Harras A, Devessa SS, Edwards BK (eds) (1993): SEER Cancer Statistics Review 1973-1990. National Cancer Institute. NIH Pub. No. 93-2789.

*Morgan RW, Claxton KW, Divine BJ, Kaplan SD, Harris VB (1981): Mortality among ethylene oxide workers. J Occup Med 23:767-770.

*Morgan RW, Wong O (1984): An epidemiologic analysis of the mortality experience of Mobil Oil Corporation employees at the Beaumont, Texas, refinery. Environmental Health Associates, Inc., Oakland, California.

Moses M (1992): Pesticides. Chapter 24 in Last JM, Wallace RR (eds). Maxcy-Rosenau-Last Public Health and Preventive Medicine. 13th Edition. Appleton and Langue.

Newell GR, Mills PK (1987): Low cancer rates in Hispanic women related to social and economic factors, Women Health 11:23-35.

*Nicholson WJ, Seidman H, Selikoff IJ, Tarr D, Clark E (1982): Brain tumors among operating engineers in the chemical and petrochemical industry in Texas and Louisiana. Ann N Y Acad Sci 381:172-180.

Olsen GW, Brondum J, Bodner KM, Kravat BA, Mandel JS, Mandell JH, Bond GG (1990b). Occupation and industry on death certificates of long-term chemical workers: concordance with work history records. Am J Ind Med 17:465-481.

*Olsen GW, Lacy SE, Cartmill JB, Kravat BA, Chamberlin SR, Spadacene NW, Lipps TE A half-century of cause-specific mortality experience of chemical manufacturing employees. In press, Am J Ind Med.

*Olsen GW, Lacy SE, Chamberlin SR, Albert DL, Arceneaux TG, Bullard LF, Stafford BA, Boswell JM (1994): Retrospective cohort mortality study of workers with potential exposure to epichlorohydrin and allyl chloride. Am J Ind Med 25:205-218.

Olsen GW, Lacy SE, Sprafka JM, Arceneaux TG, Potts TA, Kravat BA, Gondek MR, Bond GG (1991): A 5-year evaluation of a smoking cessation incentive program for chemical emmployees. Prev Med 20:774-784.

Olsen GW, Shellenberger RJ, Lacy SE, Fishbeck WA, Bond GG (1990a): A smoking cessation incentive program for chemical employees: design and evaluation. Am J Prev Med 6:200-207.

*Ott MG, Kolesar RC, Scharnweber HC, Schneider EJ, Venable JR (1980b): A mortality survey of employees engaged in the development or manufacture of styrene-based products. J Occup Med 22:445-460.

*Ott MG, Scharnweber HC, Langner RR (1980a): Mortality experience of 161 employees exposed to ethylene dibromide in two production units. Br J Ind Med 37:163-168.

Parkin DM, Wagner G, Muir C. The role of the registry in cancer control (1985). IARC Scientific Publications No. 66. Lyon: International Agency for Research on Cancer.

Perkins CI, Hoegh HJ, Wright WE, Young JL (1993): Cancer incidence and mortality by race/ethnicity in California, 1988-1990. Department of Health Services. State of California.

Pickle LW, Mason TJ, Howard N, Hoover R, Fraumeni JF (1987): Atlas of U.S. cancer mortality among whites 1950-1980. DHHS Publication No (NIH)87-2900.

*Pifer JW (1992): 1974 Texas Eastman Company mortality update through 1991. Health and Environment Laboratories, Eastman Kodak Company, August.

*Pilon T (1981): Bladder cancer mortality and occupation in males in Galveston and Harris Counties (1970-78). University of Texas School of Public Health Thesis T01157.

*Reeve GR, Bond GG, Lloyd JW, Cook RR, Waxweiler RJ, Fishbeck WA (1983b): An investigation of brain tumors among chemical plant employees using a sample-based cohort method. J Occup Med 25:387-393.

*Reeve GR, Lloyd JW, Alexander V, Leffingwell SS, Waxweiler RJ, Bell H, Halperin WE (1982): A progress report: the investigation of brain tumors at the Texas division of Dow Chemical. Ann N Y Acad Sci 381:62-72.

*Reeve GR, Thomas TL, Kelly VF, Waxweiler RJ, Itaya S (1982): A proportionate mortality study of an Oil, Chemical and Atomic Workers local in Texas City, Texas. Ann N Y Acad Sci 381:54-61.

*Reeve GR, Waxweiler RJ, Leffingwell SS (1983a): An investigation of brain and lymphopoietic cancer at a Union Carbide plant in Seadrift, Texas. Unpublished report.

*Rene AA (1982): A case-control study of prostatic cancer in Harris County, Texas. University of Texas School of Public Health Thesis T01306.

Riggan WB, Mason TJ (1983): U.S. cancer mortality rates and trends, 1950-1979. Washington DC: USGPO.

Rinsky RA, Ott G, Ward E, Greenberg H, Halperin W, Leet T. Study of mortality among chemical workers in the Kanawha Valley of West Virginia (1988): Am J Ind Med 13:429-438.

Risser DR, Weiss NS (1993): Ethnic differences in lung cancer mortality in Texas, 1991. Do age-adjusted rates give us the complete picture? Disease Prevention News, Texas Department of Health 53:1-5.

*Rom WN, Varley G, Lyon JL, Shopkow S (1982): Lung cancer mortality among residents living near the El Paso smelter. Br J Ind Med 39:269-272.

Romeis JC, Brownson RC, Davis JR, Cooperstock LR, Huang PP, Todd R, Simpson DM (1993): Minors' access to tobacco--Missouri, 1992, and Texas, 1993. MMWR 42:125-128.

*Ross CE, Enterline PE (1982): Mortality among workers from Shell Oil Company's lubricant's dewaxing unit at Deer Park, Texas. Company Report.

Rothman KJ (1986): Modern epidemiology. Boston: Little, Brown and Co. pp 171-172.

Rothstein MA, Cooper SP, Whitehead LW, Bollom D, et al. (1993): Occupational Injury and Illness in Texas. Chapter 4. Potential hazardous occupational exposures in Texas. Chapter 7. Policy options and research recommendations. University of Houston Health Law and Policy Institute.

*Shallenberger LG, Acquavella JF, Donaleski D (1992): An updated mortality study of workers in three major United States refineries and chemical plants. Br J Ind Med 49:345-354.

*Shaw GL, Falk RT, Pickle LW, Mason TJ, Buffler PA (1991): Lung cancer risk associated with cancer in relatives. J Clin Epidemiol 44:429-437.

*Shellenberger RJ (1982): Relation of occupation and mortality from pancreatic cancer among male residents of Harris County, Texas (1970-1974). University of Texas School of Public Health Thesis T01309.

*Shirts SB (1982): Lung cancer mortality patterns in Harris County (1968-1972). University of Texas School of Public Health Thesis T01310.

Shore R, Gardner MJ, Pannett B. Ethylene oxide: as assessment of the epidemiological evidence on carcinogenicity (1993): Br J Ind Med 50:971-997.

Siegel M (1993): Smoking and leukemia: evaluation of a causal hypothesis. Am J Epidemiol 138:1-9.

Siemiatycki J (1991): Risk factors for cancer in the workplace. Boca Raton, Florida: CRC Press, Inc. pp. 144-145.

Snedecor GW, Cochran WG (1967): Statistical methods. Ames: Iowa State University.

*Speers MA, Dobbins JG, Miller VS (1988): Occupational exposures and brain cancer mortality: a preliminary study of East Texas residents. Am J Ind Med 13:629-638.

*Spitz MR (1981): Environmental analysis of pancreatic cancer in Orange and Jefferson Counties, Texas. University of Texas School of Public Health Thesis T01095.

*Spitz MR, Currier RD, Fueger JJ, Babaian RJ, Newell GR (1991): Familial patterns of prostate cancer: a case-control analysis. J Urology 146:1305-1307.

*Spitz MR, Johnson CC (1985): Neuroblastoma and paternal occupation: A case-control analysis. Am J Epidemiol 121:924-929.

*Spitz MR, Tilley BC, Batsakis JG, Gibeau JM, Newell GR (1984): Risk factors for major salivary gland carcinoma. A case-comparison study. Cancer 1984; 54:1854-1859.

*Stinnett SS, Buffler PA, Eifler CW (1981): A case-control method for assessing environmental risks from multiple industrial point sources. Environ Res 25:62-74.

Stock TH, Mendez SR (1985): A survey of typical exposures to formaldehyde in Houston area residences. Am Ind Hyg Assoc J 1985; 46:313-317.

*Strong LC, Williams WR, Tainsky MA (1992): The Li-Fraumeni syndrome: from clinical epidemiology to molecular genetics. Am J Epidemiol 135:190-199.

Suarez L, Martin J (1987): Primary liver cancer mortality and incidence in Texas Mexican Americans, 1969-1980. Am J Public Health 77:631-633.

Suarez L, Martin J, Weiss N (1991): Data-based interventions for cancer control in Texas. Tex Med 87:70-77.

*Suarez L, Weiss NS, Martin J (1989): Primary liver cancer death and occupation in Texas. Am J Ind Med 15:167-175.

*Sweeny MH, Beaumont JJ, Waxweiler RJ, Halperin WE (1986): An investigation of mortality from cancer and other causes of death among workers employed at an East Texas chemical plant. Arch Environ Health 41:23-28.

*Tashjian P (1982): Decedent case control study of occupational exposure and mortality from non-Hodgkin's lymphoma in Harris and Galveston counties. University of Texas School of Public Health Thesis T01313.

*Teta MJ, Ott MG, Schnatter AR (1991): An update of mortality due to brain neoplasms and other causes among employees of a petrochemical facility. J Occup Med 33:45-51.

*Teta MJ, Perlman GD, Ott MG (1992): Mortality study of ethanol and isopropanol production workers at two facilities. Scand J Work Environ Health 18:90-96.

Texas Department of Health (1993): 1991 Texas Behavioral Risk Factor Surveillance: Final Overview.

*Thomas TL, Decoufle P, Moure-Eraso R (1980): Mortality among workers employed in petroleum refining and petrochemical plants. J Occup Med 22:97-103.

*Thomas TL, Waxweiler RJ, Crandall MS, White DW, Moure-Eraso R, Fraumeni JF Jr (1984): Cancer mortality patterns by work category in three Texas oil refineries. Am J Ind Med 6:3-16.

*Thomas TL, Waxweiler RJ, Crandall MS, White DW, Moure-Eraso R, Itaya S, Fraumeni JF Jr. (1982b): Brain cancer among OCAW members in three Texas oil refineries. Ann N Y Acad Sci 381:120-129.

*Thomas TL, Waxweiler RJ, Moure-Eraso R, Itaya S, Fraumeni JF (1982a): Mortality patterns among workers in three Texas oil refineries. J Occup Med 24:135-141.

*Tsai SP, Cowles SR, Tackett DL, Barclay MT, Ross CE (1990): Morbidity prevalence study of workers with potential exposure to epichlorohydrin. Br J Ind Med 47:392-399.

*Tsai SP, Dowd CM, Cowles SR, Ross CE (1992): A prospective study of morbidity patterns in a petroleum refinery and chemical plant. Br J Ind Med 49:516-522.

*Tsai SP, Wen CP, Weiss NS, Wong O, McClellan WA, Gibson RL (1983): Retrospective mortality and medical surveillance studies of workers in benzene areas of refineries. J Occup Med 25:685-692.

*Umphrey JL (1984): An analysis of asbestos exposure among laryngeal cancer cases and controls of coastal Texas. University of Texas School of Public Health Thesis T01525.

U.S. Bureau of the Census (1992): County Business Patterns. 1988 and 1989, on CD-ROM.

U.S. Bureau of the Census (1993): 1990 Census of Population and Housing, on CD-ROM.

U.S. Department of Health and Human Services (1990): An Atlas of State Profiles which Estimate Number of Migrant and Seasonal Farmworkers and Members of their Families. Rockville, MD: USDHHS, PHS, Health Resources and Services Administration, Migrant Health Bureau.

Vineis P, Thomas T, Hayes RB, Blot WJ, Mason TJ, Pickle LW, Correa P, Fontham ET, Schoenberg J (1988): Proportion of lung cancers in males, due to occupation, in different areas of the USA. Int J Cancer 42:851-856.

*Walker RD, Connor TH, MacDonald EJ, Trieff NM, Legator MS, MacKenzie KW Jr, Dobbins JG (1982): Correlation of mutagenic assessment of Houston air particulate extracts in relation to lung cancer mortality rates. Environ Res 28:303-312.

*Washington SD (1982): Association of gastrointestinal cancer and fluoride in water in Texas counties (1964-1976). University of Texas School of Public Health Thesis T01340.

*Waxweiler RJ, Alexander V, Leffingwell SS, Haring M, Lloyd JW (1983): Mortality from brain tumor and other causes in a cohort of petrochemical workers. JNCI 70:75-81.

*Weiss KM, Chakraborty R, Smouse PE, Buchanan AV, Strong LC (1986): Familial aggregation of cancer in Laredo, Texas: a generally low-risk Mexican-American population. Genet Epidemiol 3:121-143.

Weiss NS (1991): The epidemiology of uterine cervical cancer among white and Hispanic women in Texas. University of Texas School of Public Health Dissertation T02411.

*Wen CP, Tsai SP, Gibson RL (1982): A report of brain tumors from a retrospective cohort study of refinery workers. Ann N Y Acad Sci 381:130-138.

*Wen CP, Tsai SP, Gibson RL, McClellan WA (1984): Long-term mortality of oil refinery workers. II. Comparison of the experience of active, terminated and retired workers. J Occup Med 26:118-127.

*Wen CP, Tsai SP, McClellan WA, Gibson RL (1983): Long-term mortality study of oil refinery workers I. Mortality of hourly and salaried workers. Am J Epidemiol 118:526-542.

*Wen CP, Tsai SP, Weiss NS, Gibson RL (1986): Long-term mortality study of oil refinery workers: V. comparison of workers hired before, during, and after World War II (1940-1945) with a discussion of the impact of study designs on cohort results. Am J Ind Med 9:171-180.

*Wen CP, Tsai SP, Weiss NS, Gibson RL, Wong O, McClellan WA (1985): Long-term mortality study of oil refinery workers. IV. Exposure to the lubricating-dewaxing process. JNCI 74:11-18.

*Wen CP, Tsai SP, Weiss NS, McClellan WA, Gibson RL (1981): A population-based cohort study of brain tumor mortality among oil refinery workers with a discussion of methodological issues of SMR and PMR. Banbury Report 9:413-432.

Williams AF, Begley CE (1992): The cost of cancer in Texas. Tex Med 88:62-67.

Wong O, Raabe G (1989): Critical review of cancer epidemiology in petroleum industry employees, with a quantitative meta-analysis by cancer site. Am J Ind Med 15:283-310.

Wong O, Tabershaw IR (1980): Comments on mortality among workers employed in petroleum refining and petrochemical plants (letter). J Occup Med 22:638-640.

*Wong O, Whorton MD, Foliart DE, Ragland D (1991): An industry-wide epidemiologic study of vinyl chloride workers, 1942-1982. Am J Ind Med 20:317-334.

Wynder EL (1987): Workshop on guidelines to the epidemiology of weak associations. Prev Med 16:139-141.

*Wynder EL, Covey LS, Mabuchi K (1973): Lung cancer in women: present and future trends. JNCI 51:391-401.

*Zack M, Cannon S, Loyd D, Heath CW, Falletta JM, Jones B, Housworth J, Crowley S (1980): Cancer in children of parents exposed to hydrocarbon-related industries and occupations. Am J Epidemiol 111:329-336.

*Zadeii GR (1987): A cohort study of occupational asbestos exposure related neoplasms in Texas Gulf Coast area. University of Texas School of Public Health Dissertation T01878.

Zahm SH, Blair A (1993): Cancer among migrant and seasonal farmworkers: an epidemiologic review and research agenda. Am J Ind Med 24:753-766.

* Included in critical review

APPENDIX A

APPENDIX A

Overview of Epidemiologic Study Designs

Five major types of study designs used by epidemiologists to investigate the association between occupational and environmental exposures and disease outcomes are briefly described. An overview of the criteria used to assess causality in epidemiologic studies and to evaluate the role of chance is first presented. The study designs are then presented in ascending order from the weakest to the strongest in terms of inferring a causal relationship between a putative exposure and a disease outcome.

Causal Inference

The criteria used to assess causality in epidemiologic studies include strength or magnitude of the association, biologic credibility of the hypothesis (i.e., the existence of a known or hypothesized biologic mechanism by which the exposure might reasonably affect the risk of developing the disease in question), consistency of the findings with other epidemiologic evidence, temporal sequence of the exposure and disease outcome, and presence of a dose-response relationship (Hennekens and Buring, 1987).

Evaluating the Role of Chance

Tests of statistical significance evaluate whether or not an observed association was due to chance. Epidemiologists generally study a sample of persons rather than an entire population and thus rely on inference; hence, random variation is introduced from sample to sample that could result in observations that do not reflect the experience of the entire population.

Statistical tests of significance allow the quantification of the degree to which chance variability may account for the results observed in a given study. A measure that is often reported from tests of statistical significance is the *P* value, which is defined as the probability that an effect at least as extreme as that observed in a particular study could have occurred by chance alone if there is no relationship between the exposure and disease. By convention in medical research, a *P* value of less than or equal to 0.05 is used; this means that there is no more than a 5% chance, or 1 in 20 probability, of observing a result as extreme as that observed due solely to chance.

Because the *P* value results from a composite measure that reflects both the magnitude of the difference between the groups and the sample size, if the sample size is large, a very small effect may be statistically significant. To overcome this problem, confidence intervals, another measure that evaluates the role of chance, is often used in epidemiologic studies. The confidence interval measures, with a specified degree of assurance, the range within which the true magnitude of the effect lies. The confidence interval can provide all of the information of the *P* value in terms of deciding whether or not an association is statistically significant at a specified

corresponding proportion of dead (or diseased) persons in a presumably unexposed referent population, usually a national or regional population. A PMR greater than 100 indicates that there is a higher proportion of deaths due to a specific cause in the study group compared with the referent population. Conversely, a PMR less than 100 indicates that the study group experienced a lower proportion of deaths due to that cause.

PMR studies provide an unbiased estimate of the standardized mortality ratio (SMR) only if the overall mortality rate is the same in the exposed and referent populations. Because employed populations usually have a lower overall mortality rate than the general population (i.e., the healthy worker effect), this condition frequently is not met. It has been suggested that the healthy worker effect can be minimized by using deaths from a single generic cause as the denominator, such as all cancer deaths, and examining site-specific causes of cancer; hence, the proportional cancer mortality/morbidity ratio or PCMR has come into use (Checkoway, 1989).

Other limitations of PMR studies include that not all persons (or deaths) in the cohort are identified, thus, its validity depends on whether the deaths included are generally representative of all deaths that would be identified if follow-up of the full cohort had been done; that there is no direct measurement of exposure; and that there is an implicit assumption that the overall death rate for categories other than the ones being studied is unrelated to the exposure (Rothman, 1986; Wong and Decoufle, 1982).

Cross-sectional Studies

Cross-sectional studies are ones which measure exposure and health outcomes concurrently at a specific point in time. However, in occupational studies, historical exposure data is usually used in relation to the prevalence of disease in active workers (Pastides et al., 1991). For cancer studies, the cross-sectional study design would underestimate cases of cancers with low survival, would underestimate associations if the exposure of interest is related to shortened survival, and would miss cancers in older, retired workers, who fall in the age groups where most cancers occur. One measure of risk in a cross-sectional study is the prevalence rate ratio (PRR). The prevalence rate ratio is the ratio of the prevalence of the health outcome (cancer in this report) among the exposed compared to the prevalence among the unexposed.

Case-control Studies

The case-control design was developed as a less costly and more efficient alternative to cohort studies of chronic diseases (Cornfield, 1951; Mantel and Haenszel, 1959). Potentially, they retain many of the advantages of a cohort study but mitigate some of the difficulties of following a large cohort such as obtaining exposure data on all persons. This is because persons are selected for study who already have the disease of interest, and exposure assessment is limited to persons with the disease and to a sample of the cohort that generated the cases but did not develop the disease (Checkoway, 1989). Although case-control studies permit assessment of multiple exposures, they are limited to the assessment of one disease outcome.

Checkoway (1989) describes two types of case-control designs relevant to occupational epidemiologic studies based on the source of the cases: nested case-control and registry-based case-control studies. Nested case-control studies are embedded in the framework of an occupational cohort study and use cases identified through follow-up and a sample of other workers who did not develop the disease. Exposure histories are ascertained only on these workers. A registry-based case-control study may derive cases from various sources such as a population-based disease registry that collects data on all cases of a specific disease, or cases may be obtained from ad hoc registries such as hospital admissions, insurance claims, or disability pension awards. In this type of case-control study, controls may be obtained from the source population for the registry or from registrants with other diseases. Nested case-control studies generally have the advantages of obtaining cases and controls from a defined population and of providing the opportunity for a more detailed and direct assessment of exposure(s) and of confounding factors such as cigarette smoking, diet, and other lifestyle behaviors. Nested case-control studies are considered by some to provide the most persuasive etiologic evidence because that design combines the strengths of both case-control and cohort designs (Delzell et al., 1988).

The measure of risk in a case-control study is the odds ratio (OR). The OR is the ratio of the odds of cases exposed to a certain workplace hazard compared with the odds of controls who were exposed. An odds ratio greater than one indicates greater risk. Conversely, an odds ratios less than one indicates less risk (i.e., a protective effect).

Cohort Studies

Cohort studies are commonly used in occupational epidemiology and, in theory, are considered to provide very strong evidence for or against a causal relationship between a putative exposure and a disease outcome. Two types of cohort study designs used in occupational epidemiology are prospective cohort and historical cohort (Checkoway, 1989). In a prospective cohort study, the cohort is enumerated in the present and followed into the future whereas in an historical cohort study, the cohort is enumerated at some point in the past and is traced through some point forward in time by using record sources. Both types of cohort designs estimate and compare disease rates over a defined follow-up interval in an exposed and unexposed population initially free of disease. Both designs also permit evaluation of multiple disease outcomes and comparisons between subgroups classified by type or level of exposure.

Prospective cohort studies are useful if the goal is to assess changes in health status over a relatively brief period of time or to conduct medical surveillance on a group of workers for the occurrence of a particular disease(s). They are more costly and less efficient in terms of time and effort for studying diseases with long induction and latency periods and for studying rare diseases (e.g., those where less that 5% of the population will develop the disease during the study period). Historical cohort studies do not have these disadvantages; however, they do have the potential disadvantages that record sources needed to enumerate the cohort and describe the exposure(s) may be unavailable or incomplete, that most record sources do not have information on nonfatal diseases, and that information on confounding factors may be limited or unavailable.

The measure of risk in cohort studies usually is the Standardized Mortality (Morbidity) Ratio (SMR). An SMR is a ratio of the number of observed deaths or cases in the cohort to the number of deaths or cases expected in the cohort if the cohort experienced the same rates as a referent population, usually the prevailing rates in a national or regional population over the same time period. If the outcome is newly diagnosed cases rather than deaths, the measure of risk is referred to as a standardized incidence ratio (SIR). An SMR or SIR greater than one (or 100) indicates greater risk among the exposed cohort while an SMR or SIR less than one (or 100) indicates lower risk.

APPENDIX A REFERENCES

Checkoway H, Pearce NE, Crawford-Brown DJ (1989): Research Methods in Occupational Epidemiology. New York: Oxford University Press.

Cornfield J (1951): A method of estimating comparative rates from clinical data: application to cancer of the lung, breast and cervix. JNCI 11:1269-1275.

Delzell E, Austin H, Cole P (1988): Epidemiologic studies of the petroleum industry. Occupational Medicine: State of the Art Reviews 3:455-474.

Hennekens CH, Buring JE (1987): Epidemiology in Medicine. Boston: Little, Brown and Company.

Mantel N, Haenszel W (1959): Statistical aspects of the analysis of data from retrospective studies of disease. JNCI 22:719-748.

Pastides H, Mundt K (1991): Chemical Manufacturers Association's Epidemiology Task Group. Occupational Epidemiology Resource Manual. Washington DC: Chemical Manufacturers Association.

Rothman KJ (1986):. Modern Epidemiology. Boston: Little, Brown and Company.

Wong O, Decoufle P (1982): Methodological issues involving the standardized mortality ratio and proportionate mortality ratio in occupational studies. J Occup Med 24:229-304.

APPENDIX B

Table B-1

NINTH REVISION ICD MORTALITY CATEGORIES

PRIMARY SITE CATEGORY	ICD-9 CODE
STOMACH	151.0-151.9
COLON	153.0-153.9, 159.0
RECTUM	154.0-154.1
LIVER	155.0-155.2
GALLBLADDER	156.0-156.9
PANCREAS	157.0-157.9
LUNG, BRONCHUS	162.2-162.9
BREAST	174.0-175.9
CERVIX UTERI	180.0-180.9
OVARY	183.0
PROSTATE	185.0-185.9
BLADDER	188.0-188.9
KIDNEY, OTHER URINARY ORGANS	189.0-189.9
BRAIN, OTHER NERVOUS SYSTEM	191.0-192.9
NON-HODGKIN'S LYMPHOMAS	202.0-202.2, 200.0-200.9, 202.8-202.9
MULTIPLE MYELOMA	203.2-203.8, 203.0
LEUKEMIAS	204.0-208.9, 202.4, 203.1
TOTAL CANCER	140.0-208.9

APPENDIX C

CONTENTS
APPENDIX C

Map and Listing of Counties within
Texas Councils of Government (COGs)

Appendix C contains the map (and listing) of the boundaries of the geographic units (Councils of Governments or COGs) used in the analysis of the relative variation in cancer mortality in Texas.

FIGURE C-1

Geographic location of Texas Councils of Government (COGS)

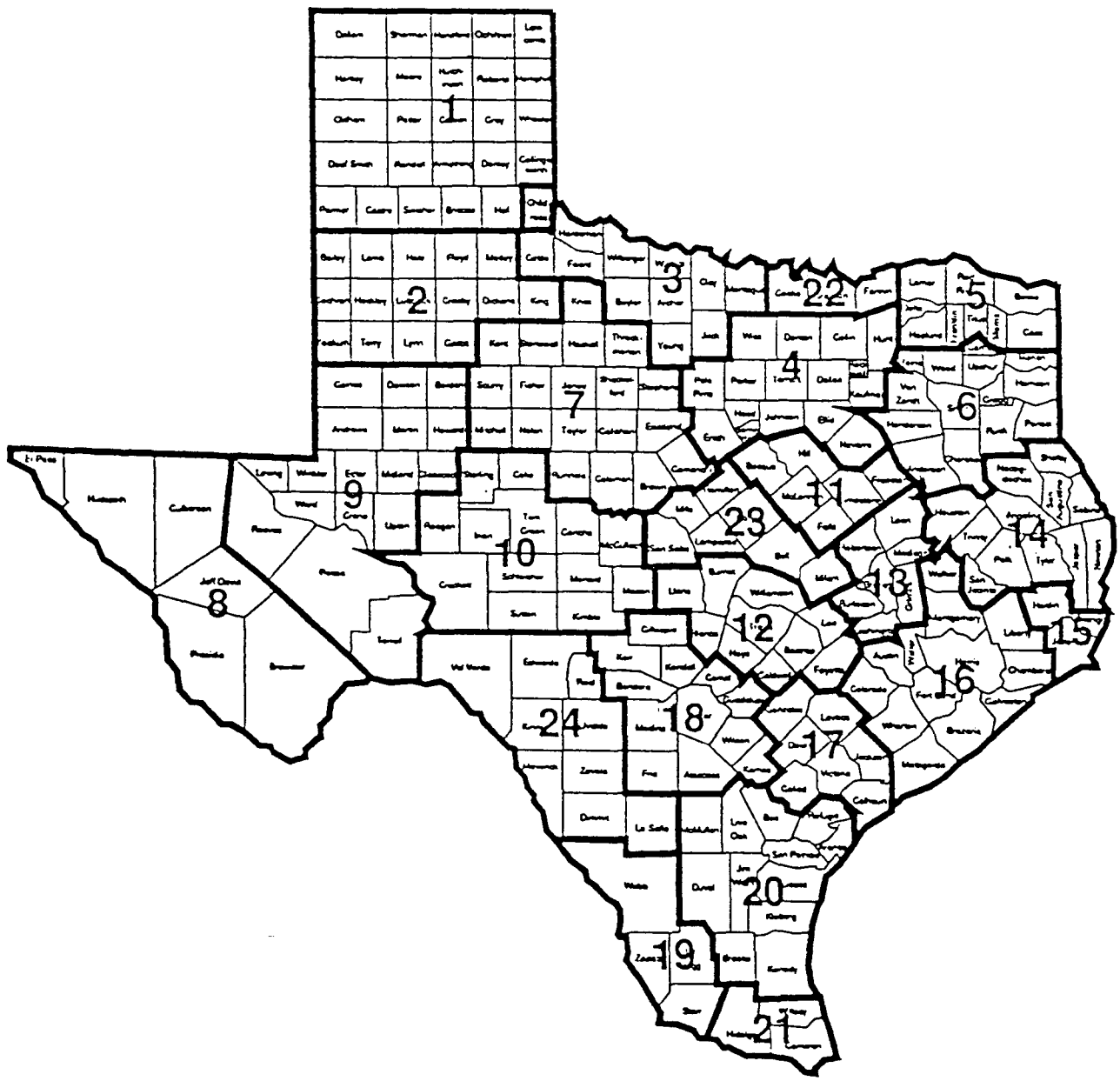

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Table C-1

Counties in the Texas Councils of Government

COG 1	COG 2	COG 3	COG 4	COG 5	COG 6
ARMSTRONG	BAILEY	ARCHER	COLLIN	BOWIE	ANDERSON
BRISCOE	COCHRAN	BAYLOR	DALLAS	CASS	CAMP
CARSON	CROSBY	CLAY	DENTON	DELTA	CHEROKEE
CASTRO	DICKENS	COTTLE	ELLIS	FRANKLIN	GREGG
CHILDRESS	FLOYD	FOARD	ERATH	HOPKINS	HARRISON
COLLINGSWORTH	GARZA	HARDEMAN	HOOD	LAMAR	HENDERSON
DALLAM	HALE	JACK	HUNT	MORRIS	MARION
DEAF SMITH	HOCKLEY	MONTAGUE	JOHNSON	RED RIVER	PANOLA
DONLEY	KING	WICHITA	KAUFMAN	TITUS	RAINS
GRAY	LAMB	WILBERGER	NAVARRE	HUDSPETH	RUSK
HALL	LUBBOCK	YOUNG	PALO PINTO	JEFF DAVIS	SMITH
HANSFORD	LYNN		PARKER	PRESIDIO	UPSHUR
HARTLEY	MOTLEY		ROCKWALL		VAN ZANDT
HEMPHILL	TERRY		SOMERVELL		WOOD
HUTCHINSON	YOAKUM		TARRANT		
LIPSCOMB			WISE		
MOORE					
OCHILTREE					
OLDHAM					
PARMER					
POTTER					
RANDALL					
ROBERTS					
SHERMAN					
SWISHER					
WHEELER					

COG 7	COG 8	COG 9	COG 10	COG 11	COG 12
BROWN	BREWSTER	ANDREWS	COKE	BOSQUE	BASTROP
CALAHAN	CULBERSON	BORDEN	CONCHO	FALLS	BLANCO
COLEMAN	EL PASO	CRANE	CROCKETT	FREESTONE	BURNET
COMANCHE		DAWSON	IRION	HILL	CALDWELL
EASTLAND		ECTOR	KIMBLE	LIMESTONE	FAYETTE
FISHER		GAINES	MASON	MCLENNEN	HAYS
HASKELL		GLASSCOCK	MCCULLOCH		LEE
JONES		HOWARD	MENARD		LLANO
KENT		LOVING	REAGAN		TRAVIS
KNOX		MARTIN	SCHLECTER		WILLIAMSON
MITCHELL		MIDLAND	STERLING		
NOLAN		PECOS	SUTTON		
RUNNELS		REEVES	TOM GREEN		
SCHACKLEFORD		TERRELL			
SCURRY		UPTON			
STEPHENS		WARD			
STONEWALL		WINKLER			
THROCKMORTON					
TAYLOR					

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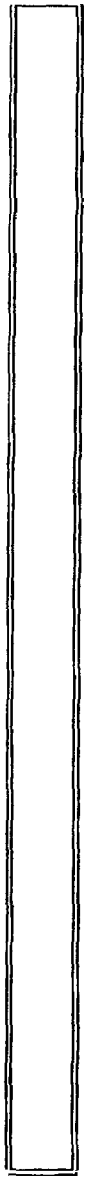
Table C-1 (Cont'd)

COG 13	COG 14	COG 15	COG 16	COG 17	COG 18
BRAZOS BURLESON GRIMES LEON MADISON ROBERTSON WASHINGTON	ANGELINA HOUSTON JASPER NACOGDOCHES NEWTON POLK SABINE SAN AUGUSTINE SAN JACINTO SHELBY	HARDIN JEFFERSON ORANGE	AUSTIN BRAZORIA CHAMBERS COLORADO FT. BEND GALVESTON HARRIS LIBERTY MATAGORDA MONTGOMERY WALKER WALLER WHARTON	CALHOUN DEWITT GOLIAD GONZALES JACKSON LAVACA VICTORIA	ATASCOSA BANDERA BEXAR COMAL FRIO GILLEPSIE GUADALUPE KARNES KENDALL KERR MEDINA WILSON
COG 19	COG 20	COG 21	COG 22	COG 23	COG 24
HOGG STARR WEBB ZAPATA	ARANSAS BEE BROOKS DUVAL JIM WELLS KENEDY KLEBERG LIVE OAK MCMULLEN NUECES REFUGIO SAN PATRICIO	CAMERON HIDALGO WILLACY	COOKE FANNIN GRAYSON	BELL CORYELL HAMILTON LAMPASAS MILAM MILLS SAN SABA	DIMMIT EDWARDS KINNEY LASALLE MAVERICK REAL UVALDE VAL VERDE ZAVALA

23841133



CONTENTS

APPENDIX D
Time Trends in Age-Adjusted Cancer Mortality Rates for Seventeen Cancers (other than lung) in the U.S. and Texas, by Race/Ethnicity and Sex, 1980-1990

Appendix D includes the graphs of the age-adjusted mortality rates by race/ethnicity and sex over time (1980-1990) for seventeen causes of cancer deaths (other than lung and total shown in text) in the U.S. and Texas. Significantly increasing or decreasing trends in age-adjusted cancer mortality rates are denoted by an asterisk. The selected cancer sites include the five leading causes of cancer deaths (excluding lung) as well as those considered to be possibly related to occupational or environmental exposures. Legend notation is consistent throughout Appendix D as follows:

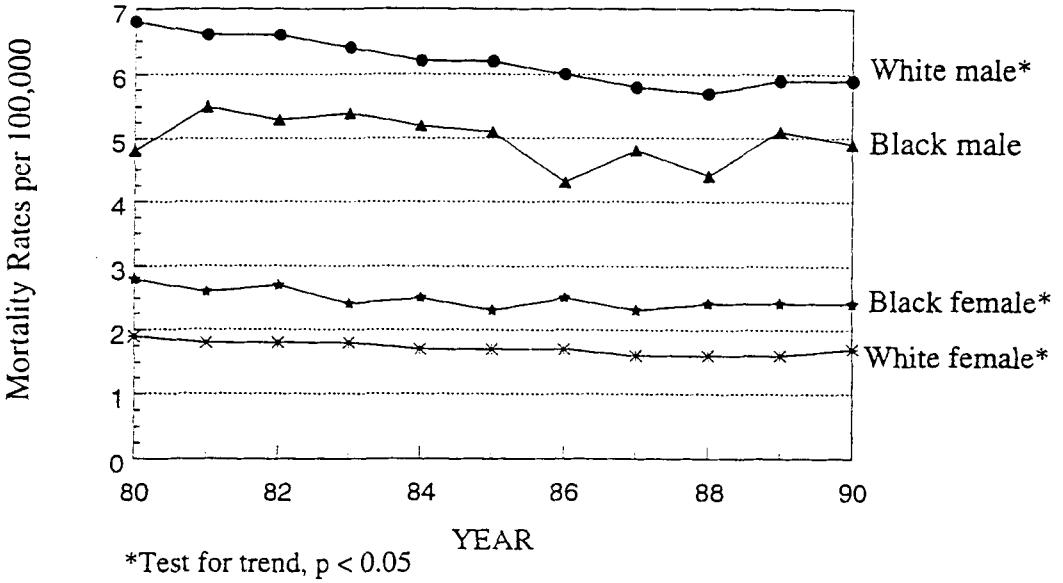
LEGEND:

●	Anglo/white male	*	Anglo/white female
■	Hispanic male	♦	Hispanic female
▲	Black male	★	Black female

The figures are listed in alphabetical order with the exception of rectum, which is presented with colon.

FIGURE D-1

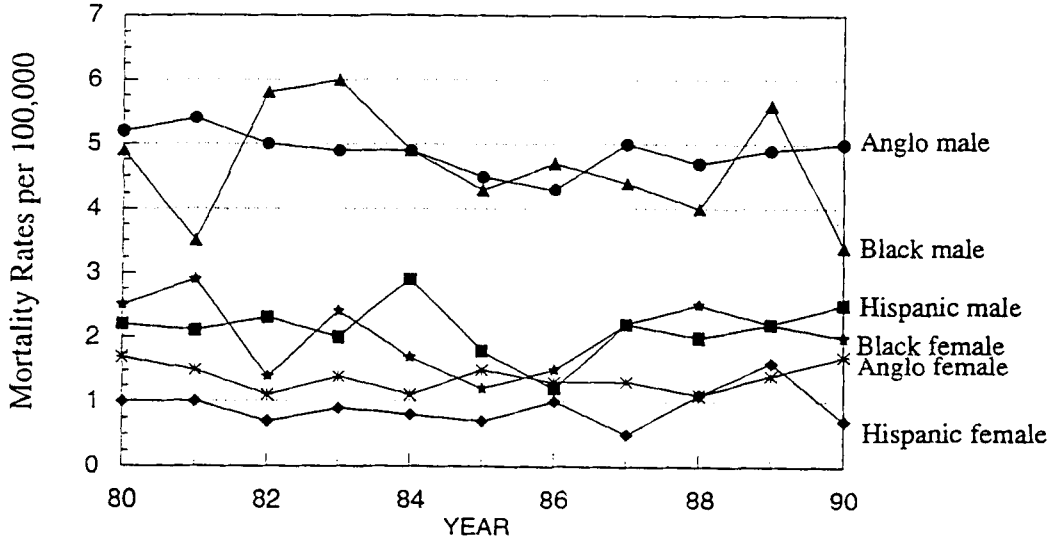
Age-Adjusted Bladder Cancer Mortality in the U.S. by Race and Sex, 1980-1990



*Test for trend, $p < 0.05$

Source: SEER, Cancer Statistics Review, 1973-1990

Age-Adjusted Bladder Cancer Mortality in Texas by Race/Ethnicity and Sex, 1980-1990

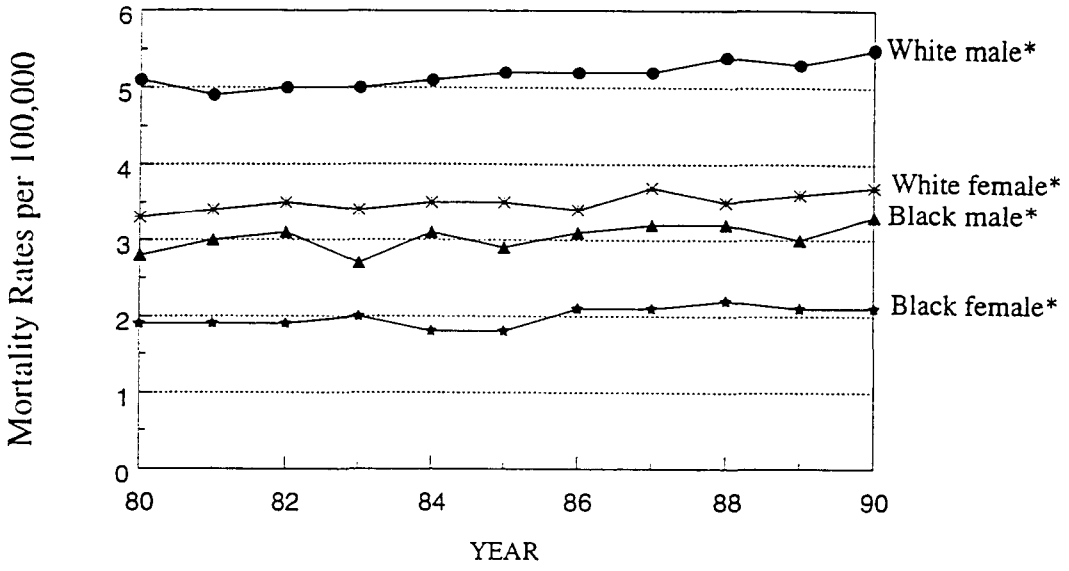


Source: Cancer Registry Division, Texas Department of Health

2384135

FIGURE D-2

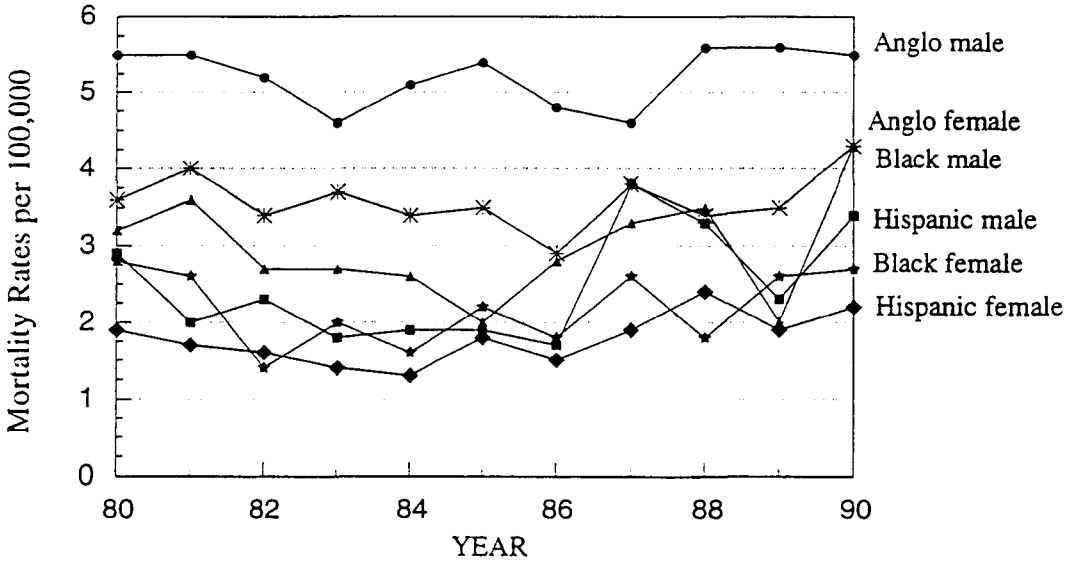
Age-Adjusted Brain Cancer Mortality in the U.S. by Race and Sex, 1980-1990



*Test for trend, $p < 0.05$

Source: SEER, Cancer Statistics Review, 1973-1990

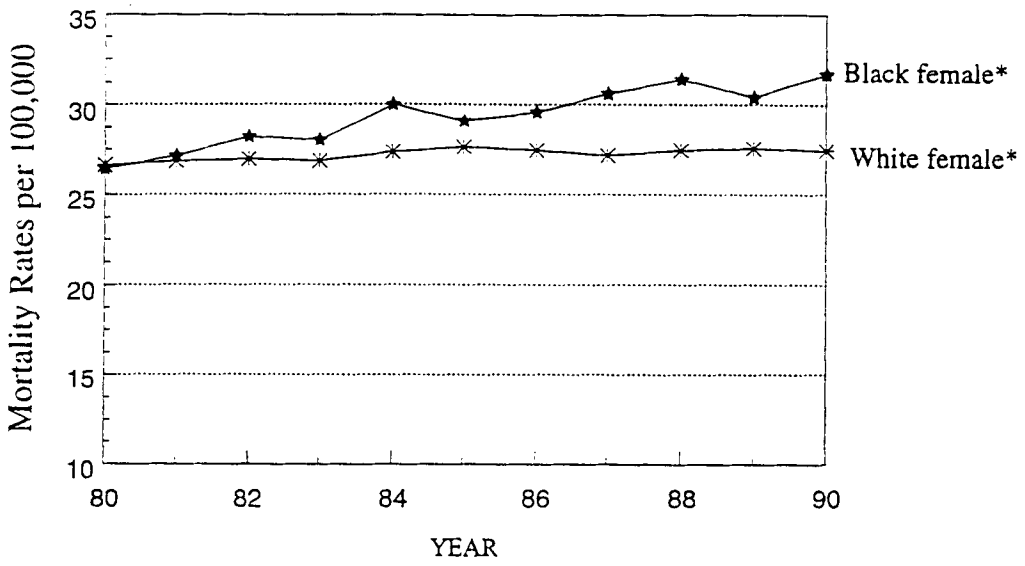
Age-Adjusted Brain Cancer Mortality in Texas by Race/Ethnicity and Sex, 1980-1990



Source: Cancer Registry Division, Texas Department of Health

FIGURE D-3

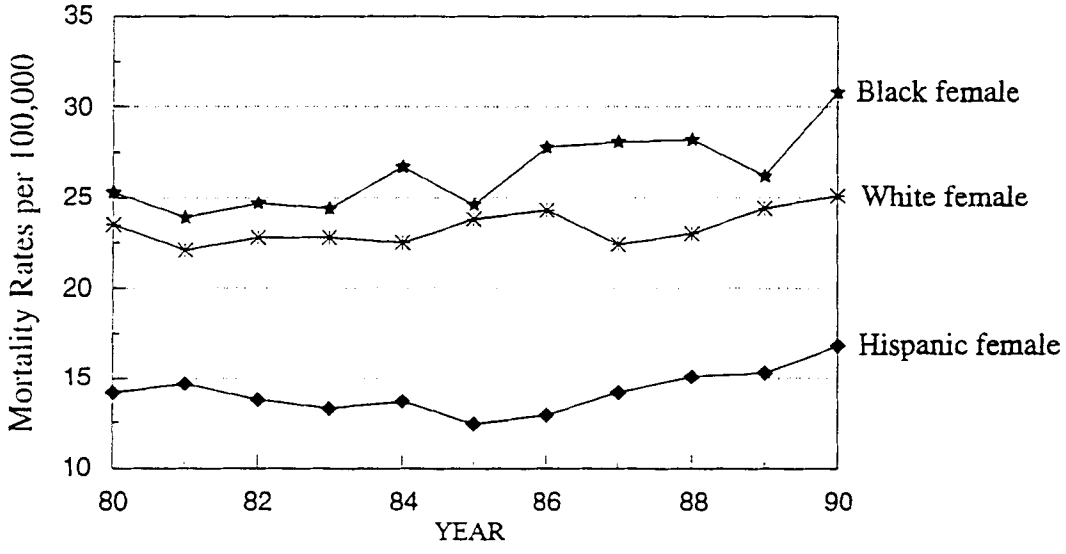
Age-Adjusted Breast Cancer Mortality in the U.S. by Race, 1980-1990



*Test for trend, $p < 0.05$

Source: SEER, Cancer Statistics Review, 1973-1990

Age-Adjusted Breast Cancer Mortality in Texas by Race/Ethnicity, 1980-1990

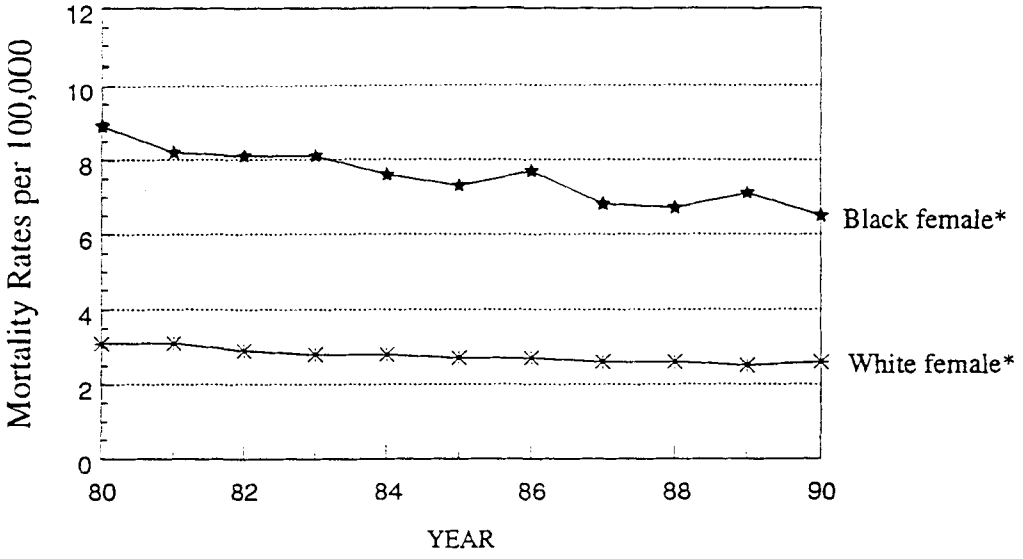


Source: Cancer Registry Division, Texas Department of Health

23841137

FIGURE D-4

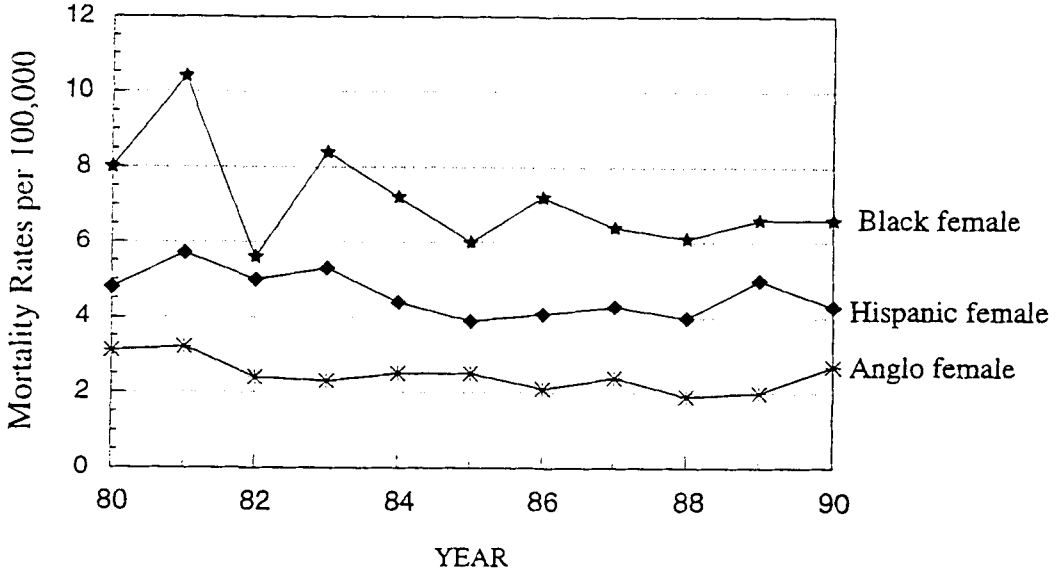
Age-Adjusted Cervix Cancer Mortality in the U.S. by Race, 1980-1990



*Test for trend, $p < 0.05$

Source: SEER, Cancer Statistics Review, 1973-1990

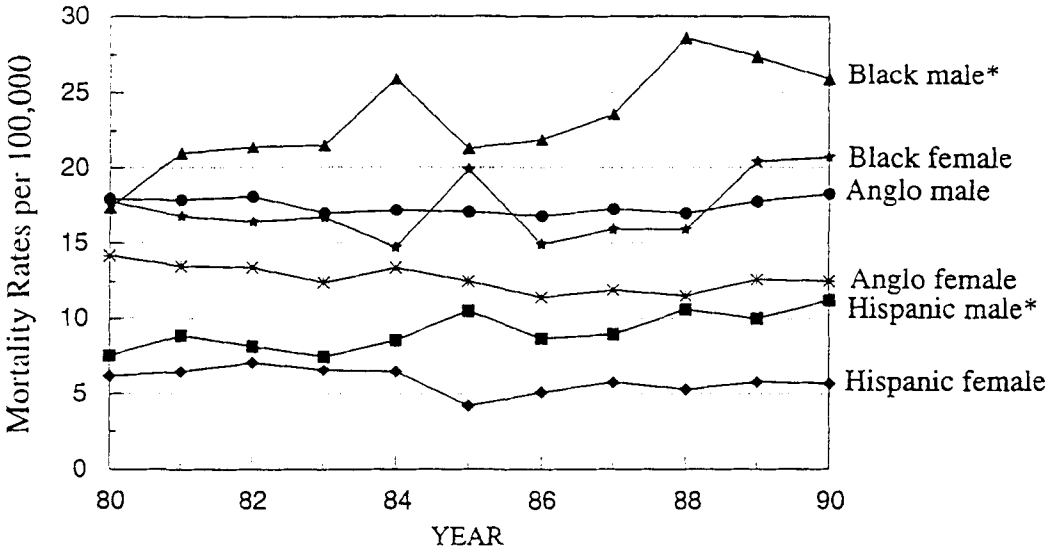
Age-Adjusted Cervix Cancer Mortality in Texas by Race/Ethnicity, 1980-1990



Source: Cancer Registry Division, Texas Department of Health

FIGURE D-5

Age-Adjusted Colon Cancer Mortality in Texas by Race/Ethnicity and Sex, 1980-1990

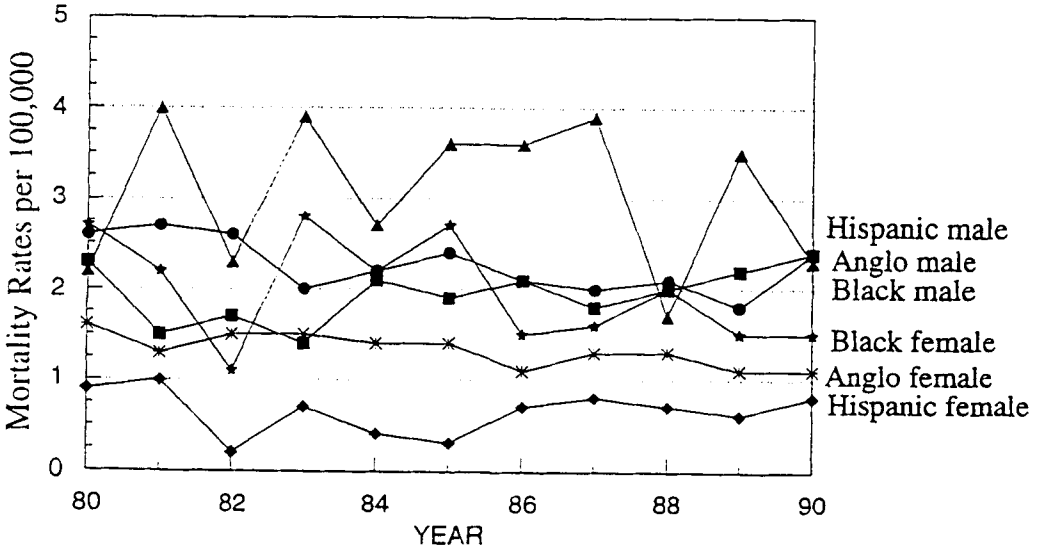


*Test for trend, $p < 0.05$

Source: Cancer Registry Division, Texas Department of Health

(Note: U.S. colon cancer mortality rates not available.)

Age-Adjusted Rectum Cancer Mortality in Texas by Race/Ethnicity and Sex, 1980-1990

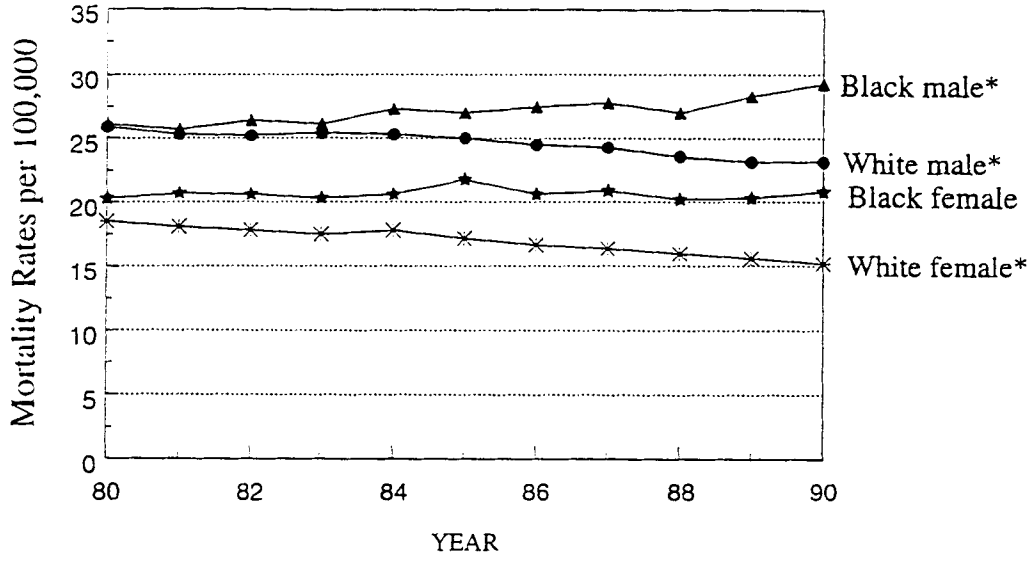


Source: Cancer Registry Division, Texas Department of Health

(Note: U.S. rectum cancer mortality rates not available.)

FIGURE D-6

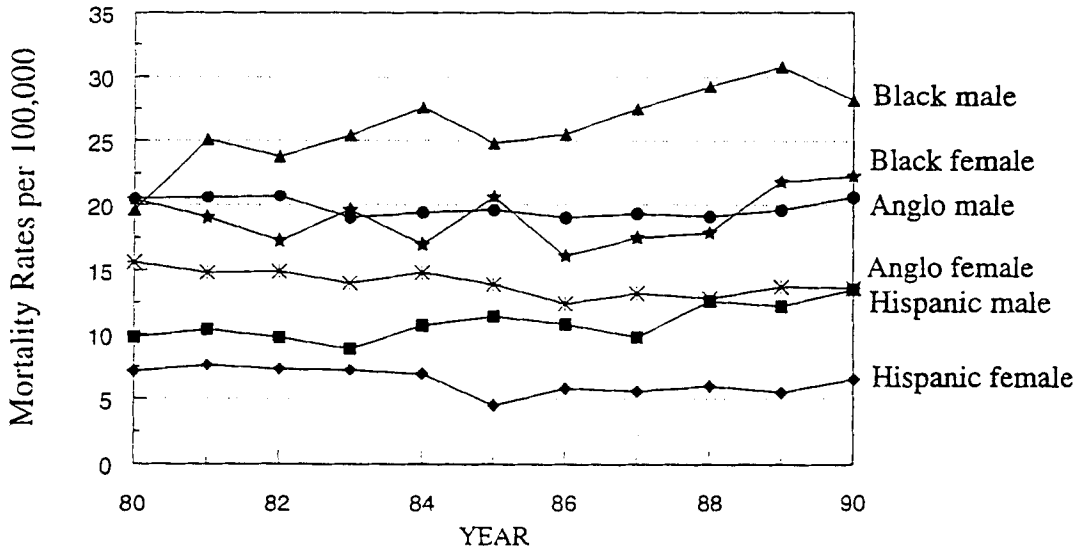
Age-Adjusted Colorectal Cancer Mortality in the U.S. by Race and Sex, 1980-1990



*Test for trend, $p < 0.05$

Source: SEER, Cancer Statistics Review, 1973-1990

Age-Adjusted Colorectal Cancer Mortality in Texas by Race/Ethnicity and Sex, 1980-1990

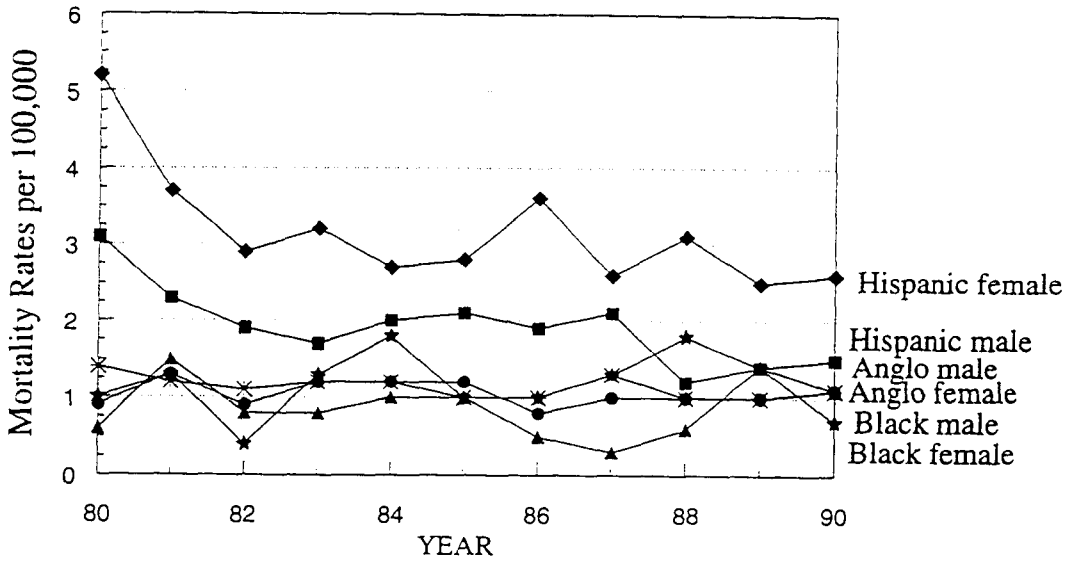


Source: Cancer Registry Division, Texas Department of Health

(Note: Test for trend not available for Texas colon and rectum cancer combined. Please see colon and rectum cancer for Texas presented separately.)

FIGURE D-7

Age-Adjusted Gallbladder Cancer Mortality in Texas by Race/Ethnicity and Sex, 1980-1990



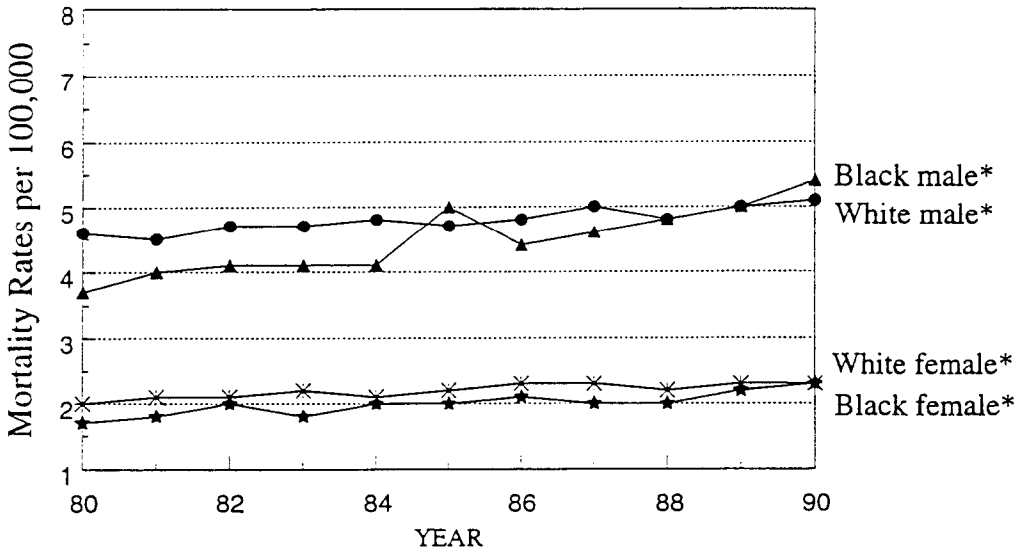
Source: Cancer Registry Division, Texas Department of Health

(NOTE: U.S. gallbladder mortality rates not available by year from SEER)

2384.1.141

FIGURE D-8

Age-Adjusted Kidney Cancer Mortality in the U.S. by Race and Sex, 1980-1990

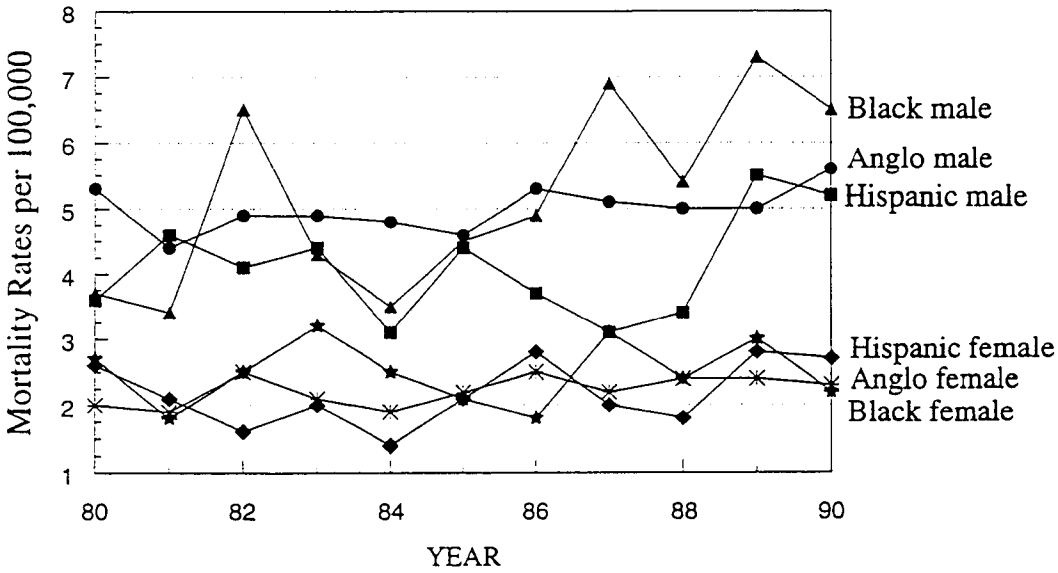


*Test for trend, $p < 0.05$

Source: SEER, Cancer Statistics Review, 1973-1990

Note: Rates do not include ureter and urinary system cancers.

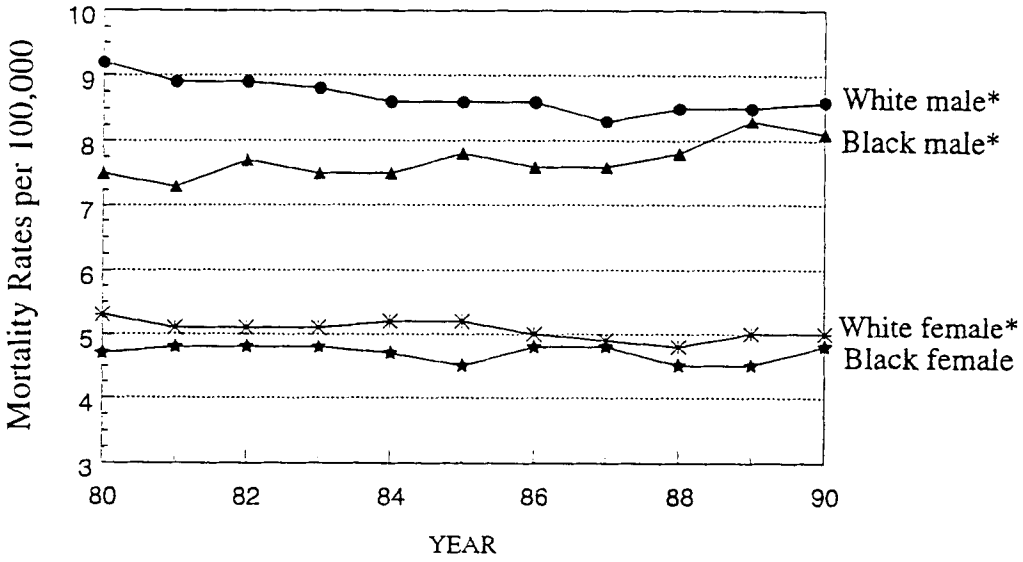
Age-Adjusted Kidney Cancer Mortality in Texas by Race/Ethnicity and Sex, 1980-1990



Source: Cancer Registry Division, Texas Department of Health

FIGURE D-9

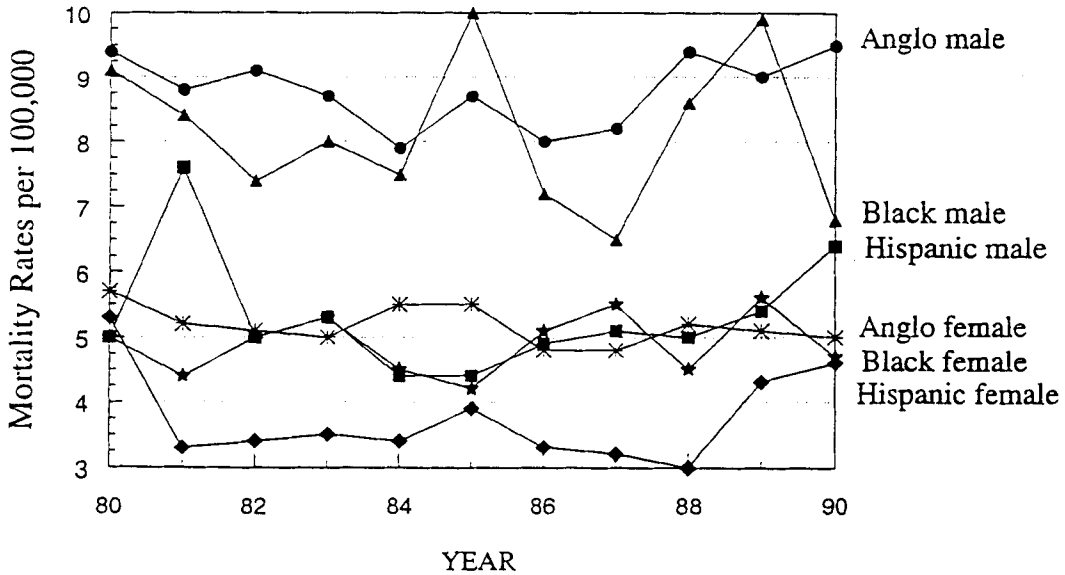
Age-Adjusted Leukemia Mortality in the U.S. by Race and Sex, 1980-1990



*Test for trend, $p < 0.05$

Source: SEER, Cancer Statistics Review, 1973-1990

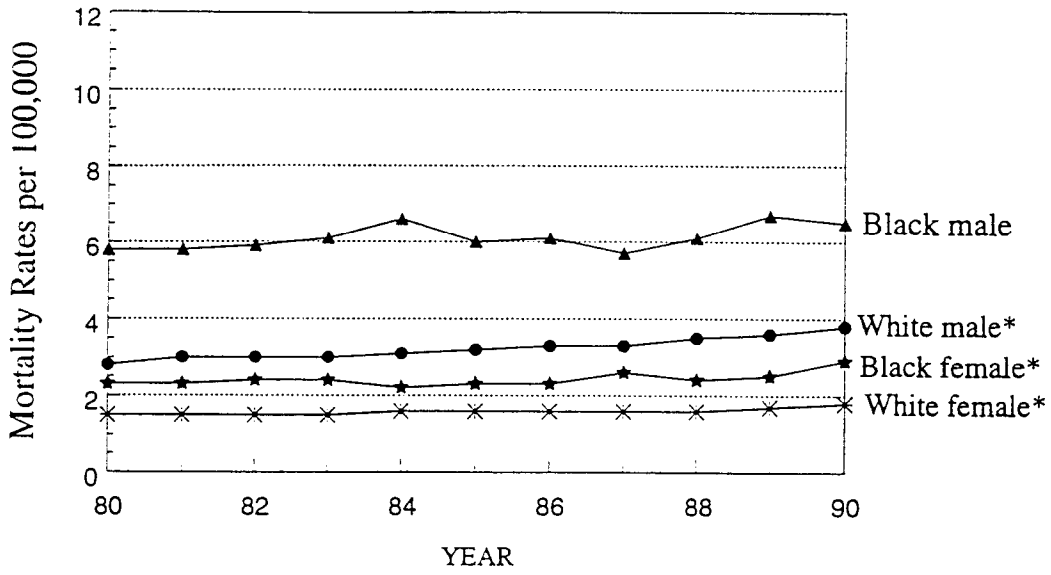
Age-Adjusted Leukemia Mortality in Texas by Race/Ethnicity and Sex, 1980-1990



Source: Cancer Registry Division, Texas Department of Health

FIGURE D-10

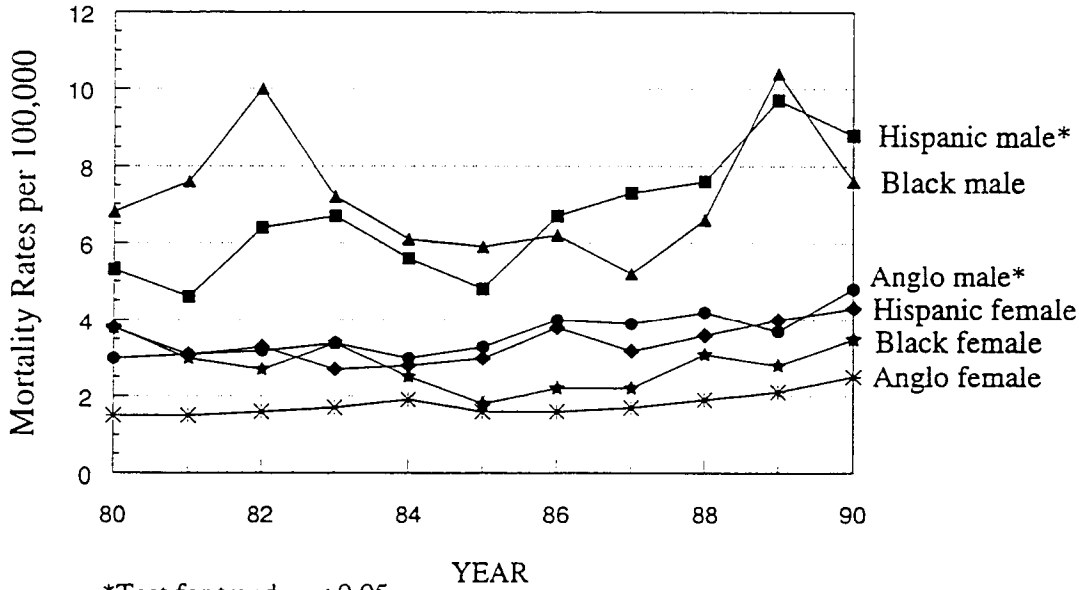
Age-Adjusted Liver Cancer Mortality in the U.S. by Race and Sex, 1980-1990



*Test for trend, $p < 0.05$

Source: SEER, Cancer Statistics Review, 1973-1990

Age-Adjusted Liver Cancer Mortality in Texas by Race/Ethnicity and Sex, 1980-1990



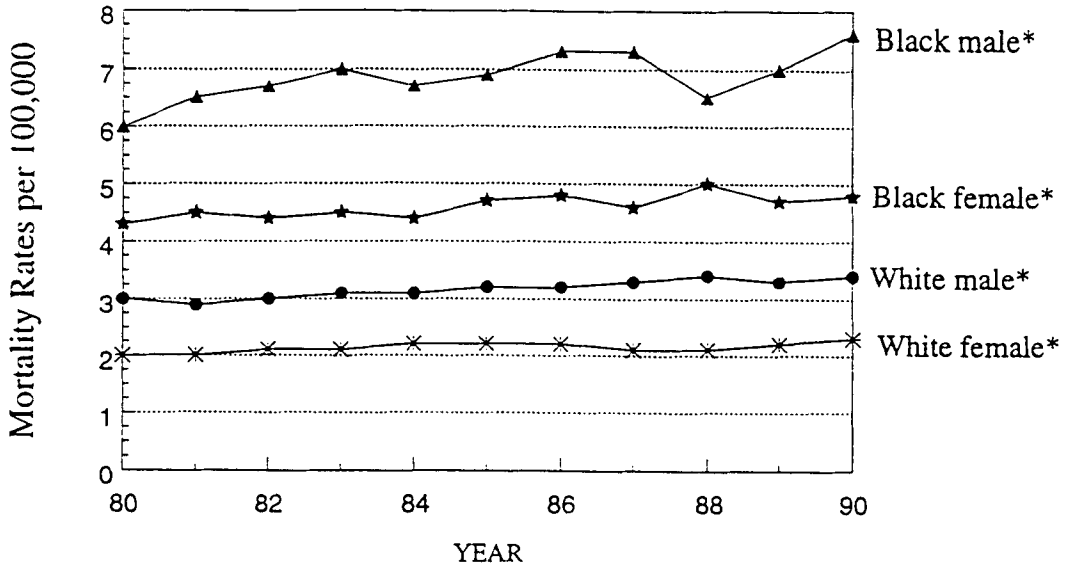
*Test for trend, $p < 0.05$

Source: Cancer Registry Division, Texas Department of Health

23841144

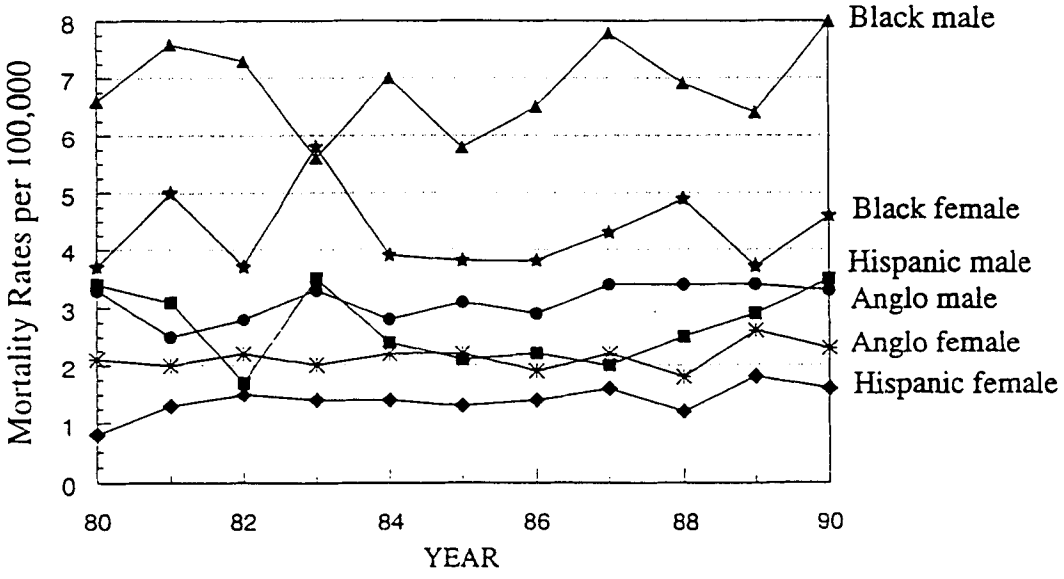
FIGURE D-11

Age-Adjusted Multiple Myeloma Mortality in the U.S. by Race and Sex, 1980-1990



*Test for trend, $p < 0.05$
Source: SEER, Cancer Statistics Review, 1973-1990

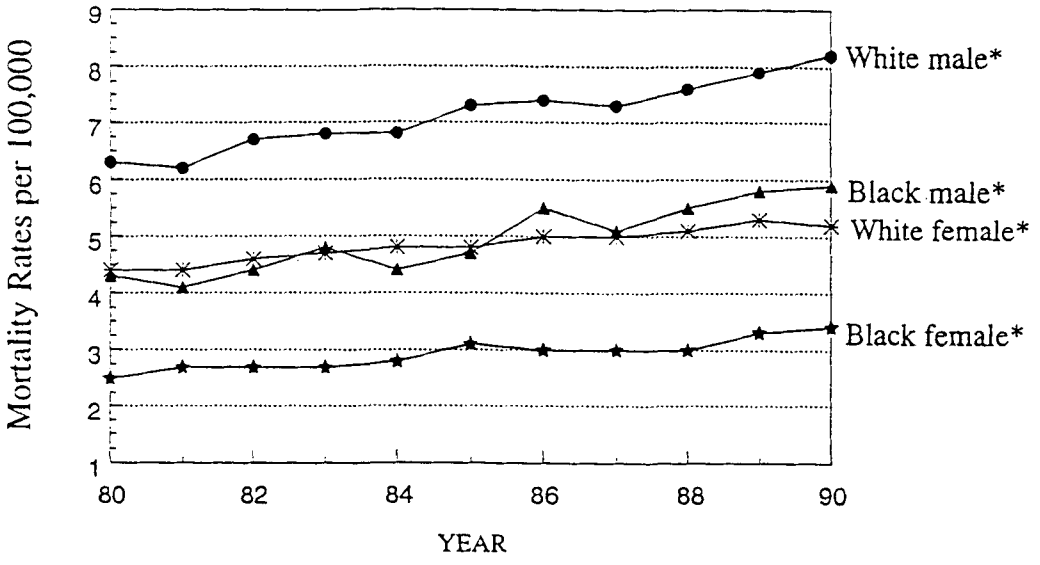
Age-Adjusted Multiple Myeloma Mortality in Texas by Race/Ethnicity and Sex, 1980-1990



Source: Cancer Registry Division, Texas Department of Health

FIGURE D-12

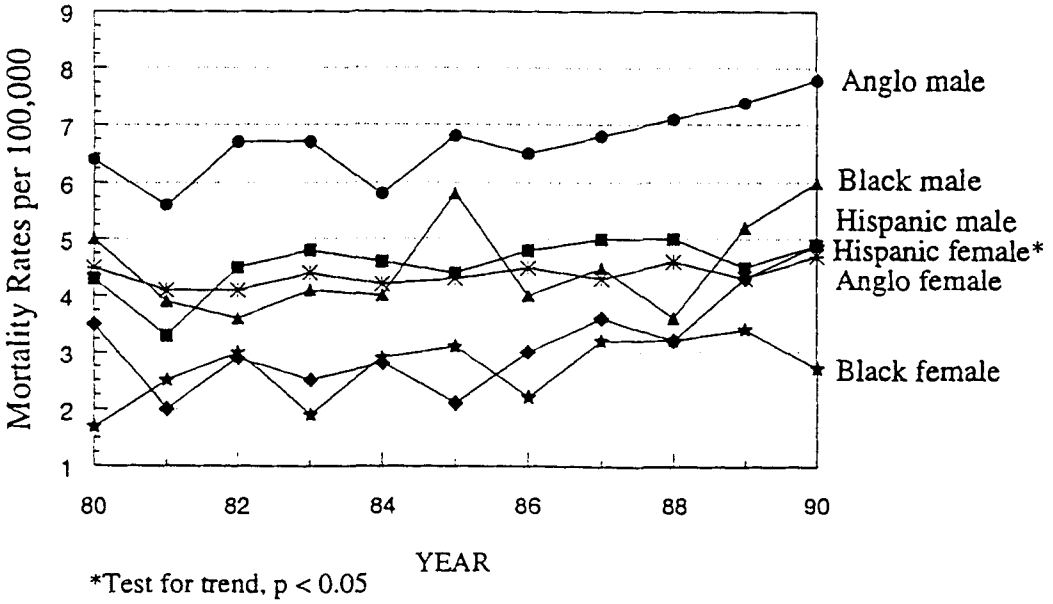
Age-Adjusted Non-Hodgkin's Lymphoma Mortality in the U.S. by Race and Sex, 1980-1990



*Test for trend, $p < 0.05$

Source: SEER, Cancer Statistics Review, 1973-1990

Age-Adjusted Non-Hodgkin's Lymphoma Mortality in Texas by Race/Ethnicity and Sex, 1980-1990



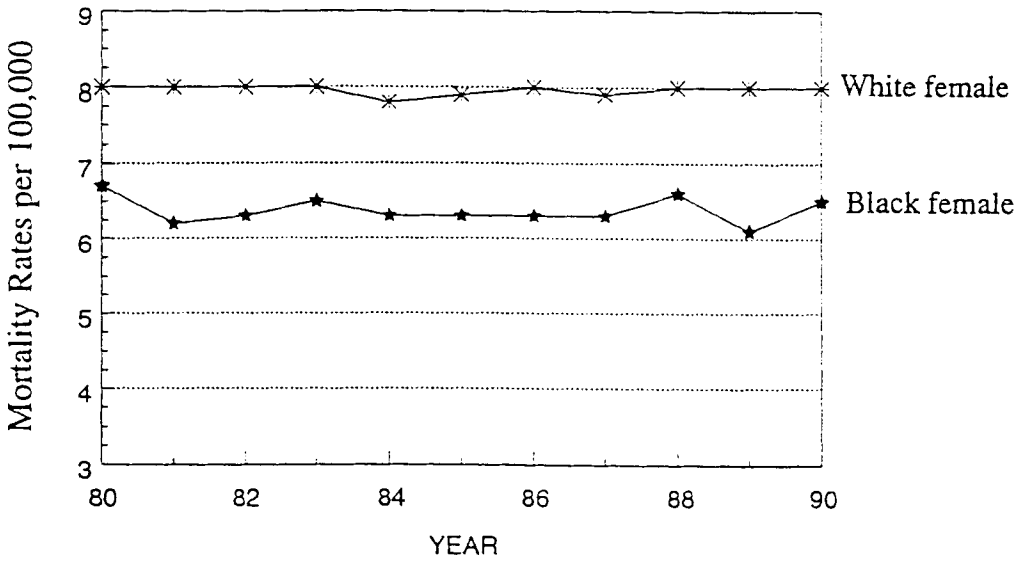
*Test for trend, $p < 0.05$

Source: Cancer Registry Division, Texas Department of Health

2384146

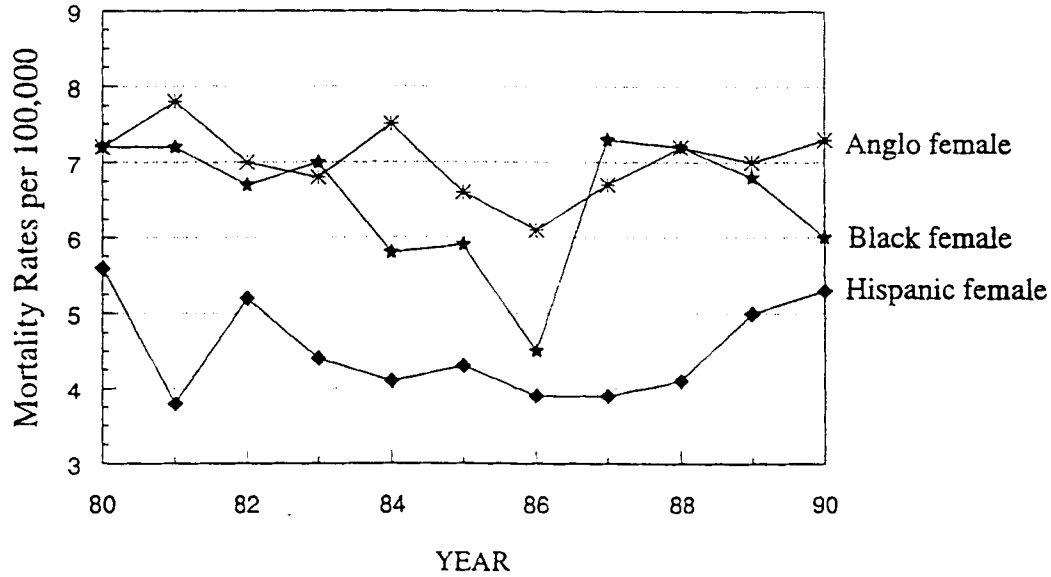
FIGURE D-13

Age-Adjusted Ovary Cancer Mortality in the U.S. by Race, 1980-1990



Source: SEER, Cancer Statistics Review, 1980-1990

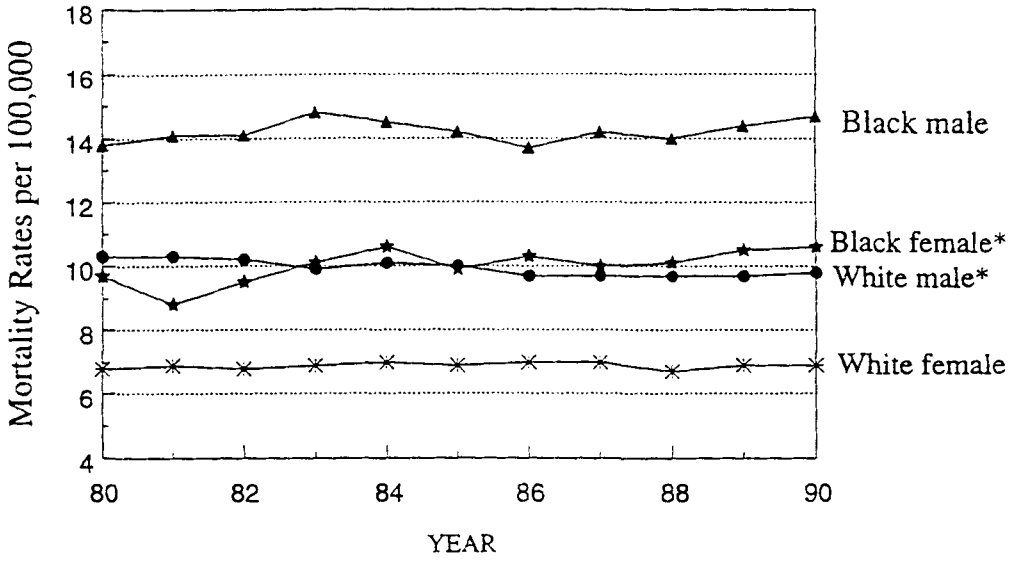
Age-Adjusted Ovary Cancer Mortality in Texas by Race/Ethnicity, 1980-1990



Source: Cancer Registry Division, Texas Department of Health

FIGURE D-14

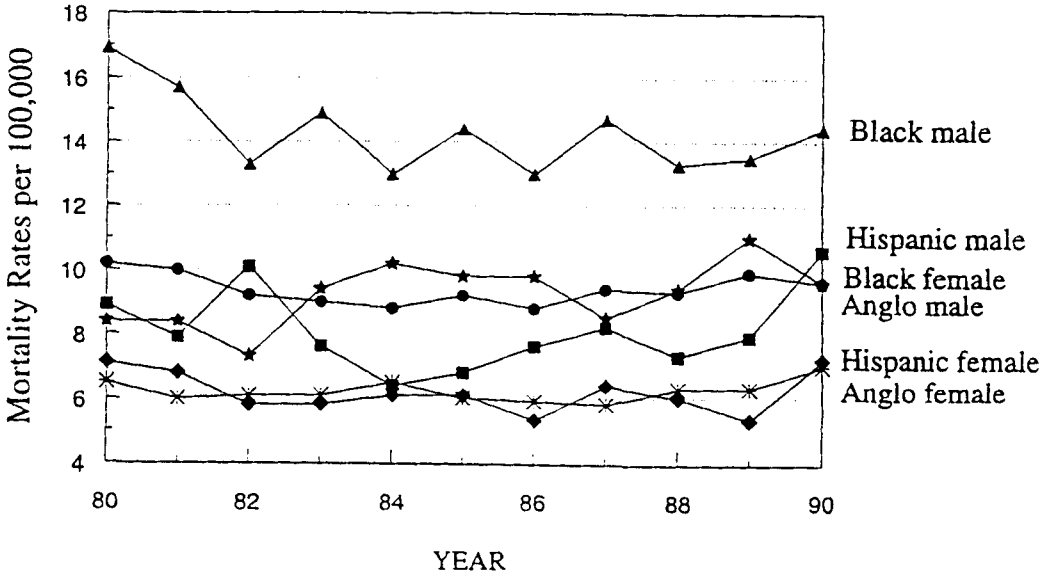
Age-Adjusted Pancreas Cancer Mortality in the U.S. by Race and Sex, 1980-1990



*Test for trend, $p < 0.05$

Source: SEER, Cancer Statistics Review, 1973-1990

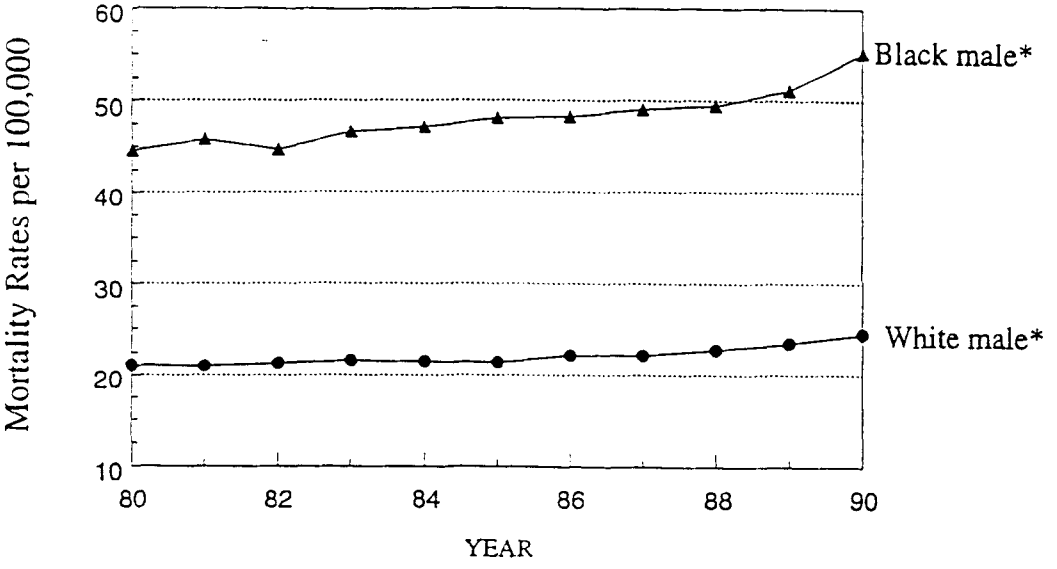
Age-Adjusted Pancreas Cancer Mortality in Texas by Race/Ethnicity and Sex, 1980-1990



Source: Cancer Registry Division, Texas Department of Health

FIGURE D-15

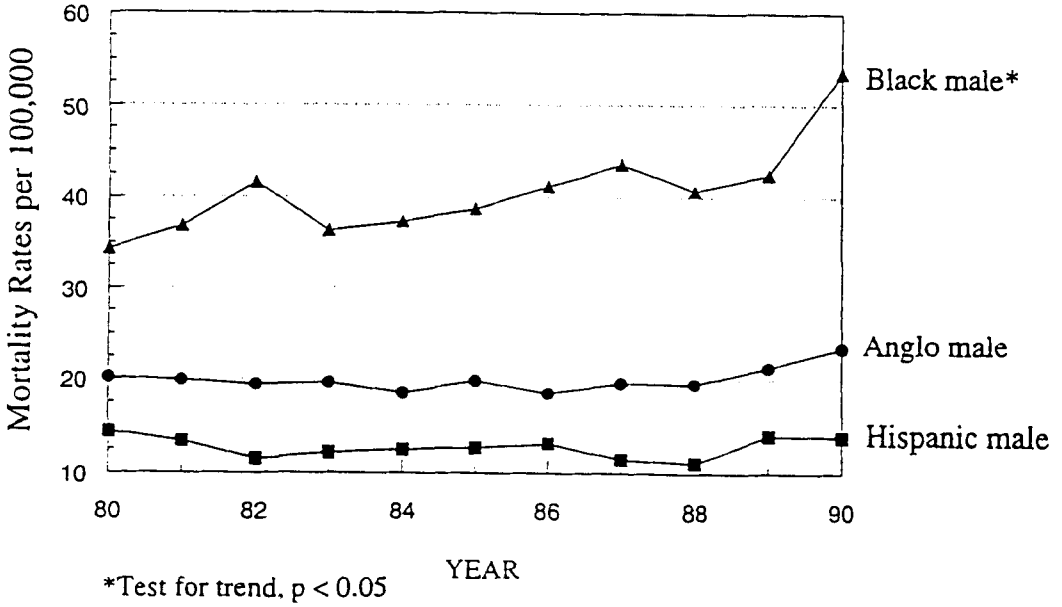
Age-Adjusted Prostate Cancer Mortality in the U.S. by Race, 1980-1990



*Test for trend, $p < 0.05$

Source: SEER, Cancer Statistics Review, 1973-1990

Age-Adjusted Prostate Cancer Mortality in Texas by Race/Ethnicity, 1980-1990

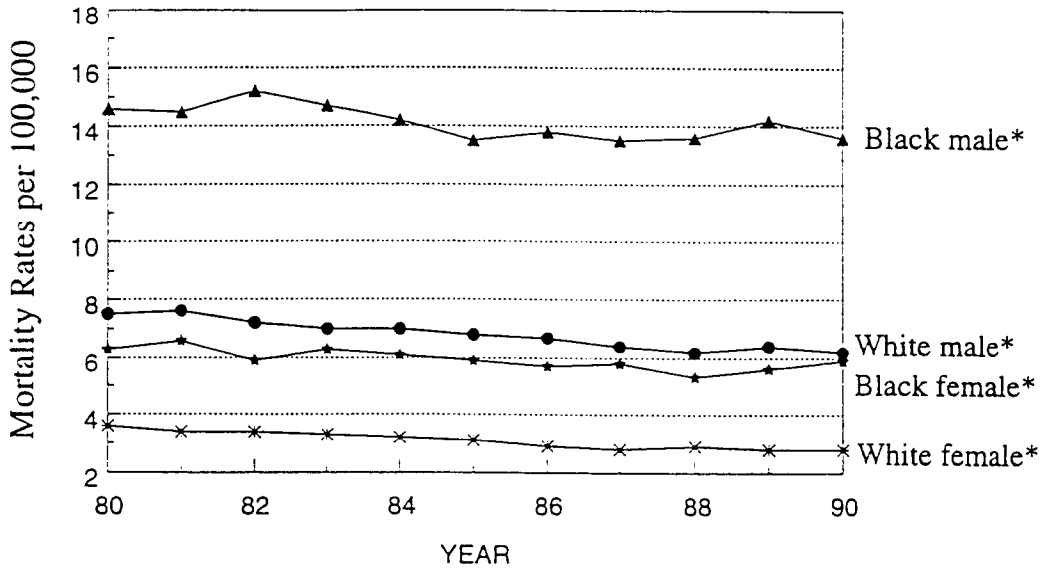


*Test for trend, $p < 0.05$

Source: Cancer Registry Division, Texas Department of Health

FIGURE D-16

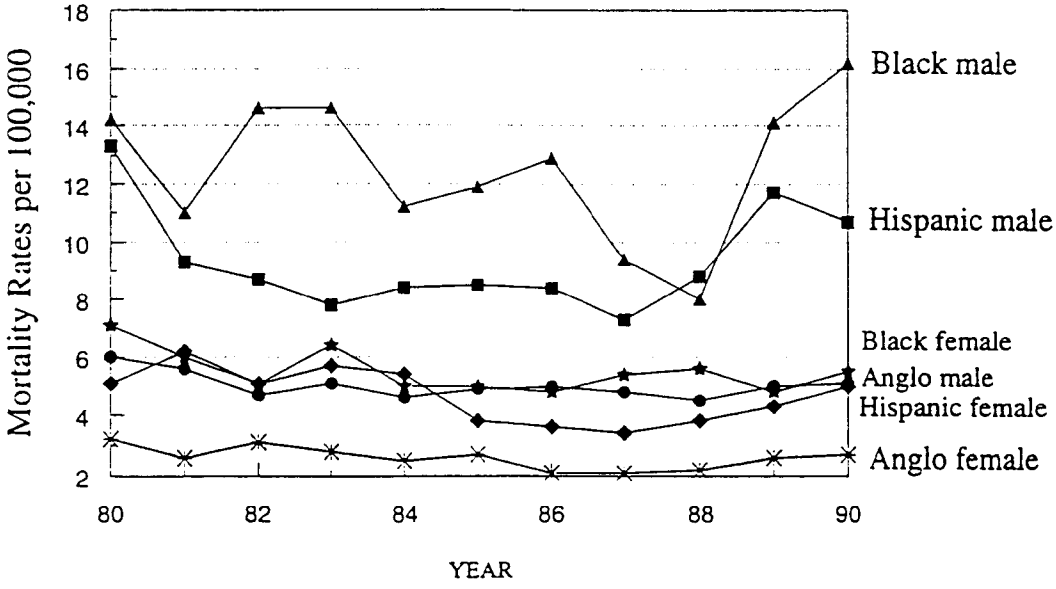
Age-Adjusted Stomach Cancer Mortality in the U.S. by Race and Sex, 1980-1990



*Test for trend, $p < 0.05$

Source: SEER, Cancer Statistics Review, 1973-1990

Age-Adjusted Stomach Cancer Mortality in Texas by Race/Ethnicity and Sex, 1980-1990



Source: Cancer Registry Division, Texas Department of Health

2384150

APPENDIX E

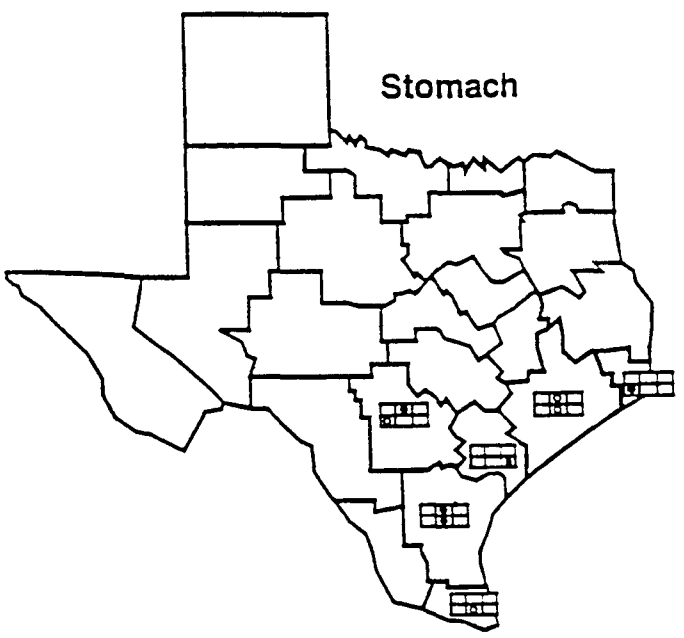
CONTENTS

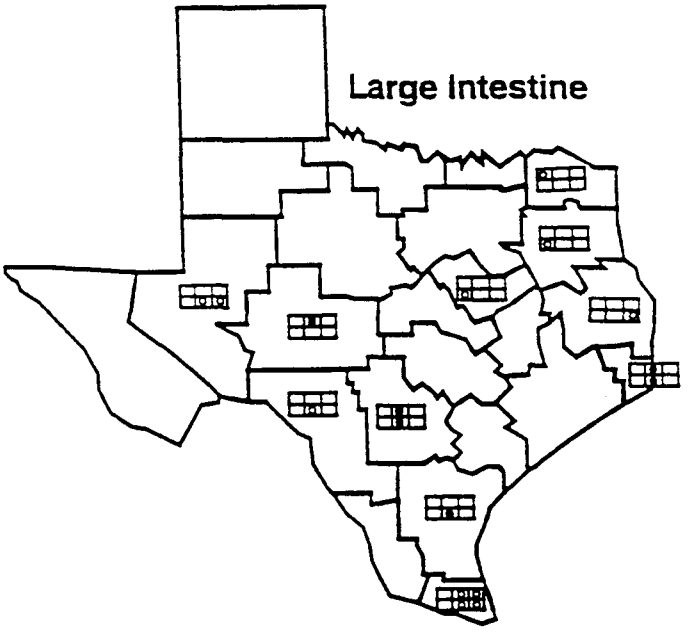
APPENDIX E
Maps of Geographic Variation in Cancer Mortality
in Texas: Excesses and Deficits

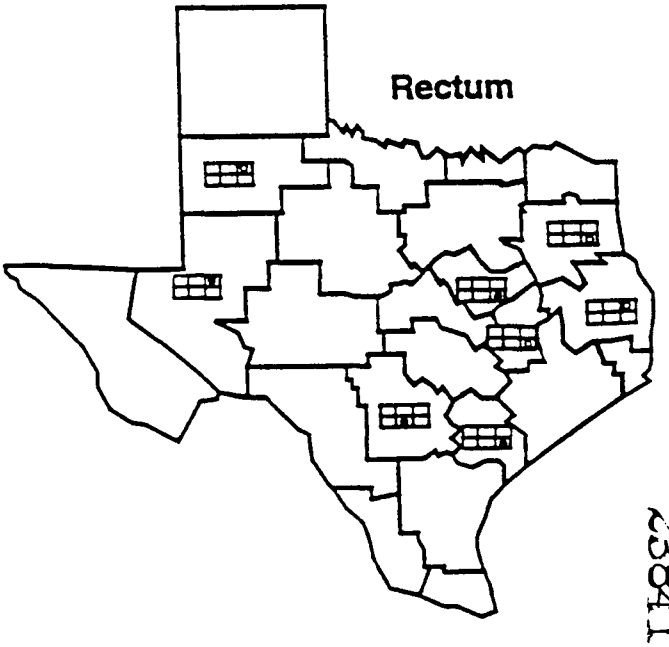
Appendix E is based on the map (and listing) of the boundaries of the geographic units (Councils of Governments or COGs) used in the analysis of the relative variation in cancer mortality in Texas. Figures E-1 to E-6 display the significant excesses and deficits in cancer mortality from 1980-1991 by geographic regions for various cancer sites that met the following criteria: SMR ≥ 1.20 for an excess and ≤ 0.83 for a deficit, alpha < 0.05, and at least 12 deaths occurred during the 12 year period. Lack of notation of an excess or deficit indicates that no qualifying SMR occurred or there were insufficient numbers of deaths for assessment. The SMR for the state planning regions are shown for the following cancer types:

FIGURE E-1

Standardized Mortality Ratios (SMRs) Comparing State Planning Regions with the State of Texas by Ethnicity, Sex and Cancer Site, 1980-1991







Legend:

	B	H	W*
Female	●	●	●
Male	●	●	●

SMR ≥ 120, $\alpha < 0.05$ and 12 or more deaths occurred over the 12 yr period

	B	H	W
Female	○	○	○
Male	○	○	○

SMR ≤ 83, $\alpha < 0.05$ and 12 or more deaths occurred over the 12 yr period

Blank = No qualifying excesses or deficits, or insufficient numbers of deaths

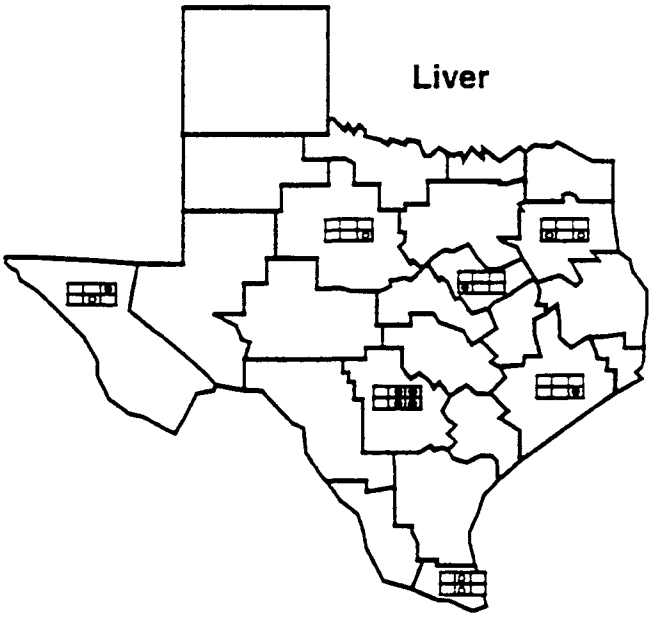
* B = Black, H = Hispanic, W = White/Anglo

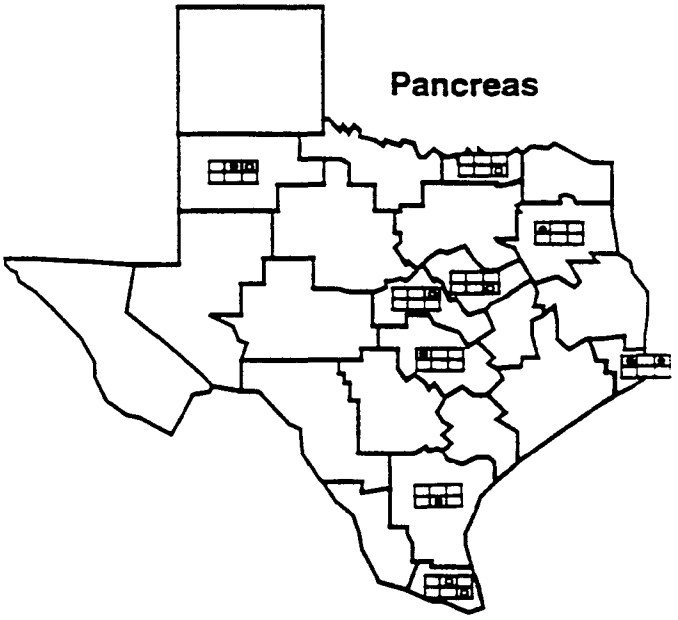
Source: Unpublished data, Cancer Registry Division, Texas Department of Health

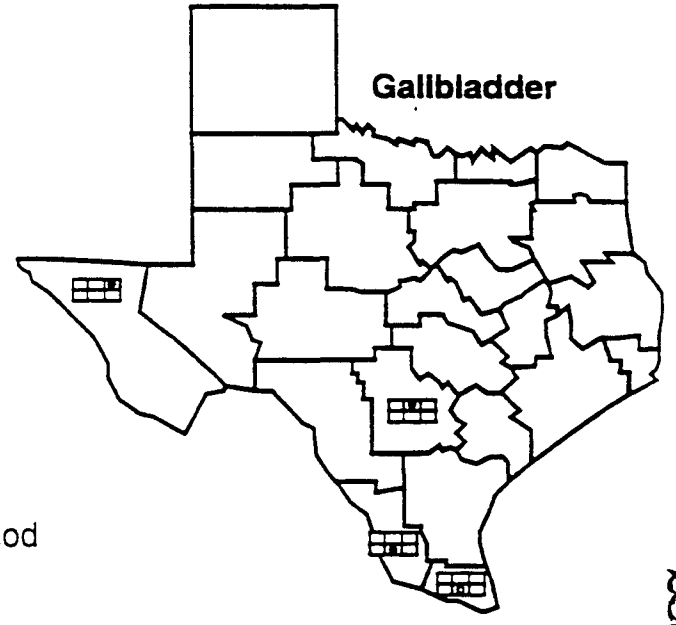
2384153

FIGURE E-2

Standardized Mortality Ratios (SMRs) Comparing State Planning Regions with the State of Texas by Ethnicity, Sex and Cancer Site, 1980-1991







Legend:

	B	H	W*
Female	●	●	●
Male	●	●	●

SMR ≥120, $\alpha < 0.05$ and more than 12 deaths occurred over the 12 yr period

	B	H	W
Female	○	○	○
Male	○	○	○

SMR ≤ 83, $\alpha < 0.05$ and more than 12 deaths occurred over the 12 yr period

Blank = No qualifying excesses or deficits, or insufficient numbers of deaths

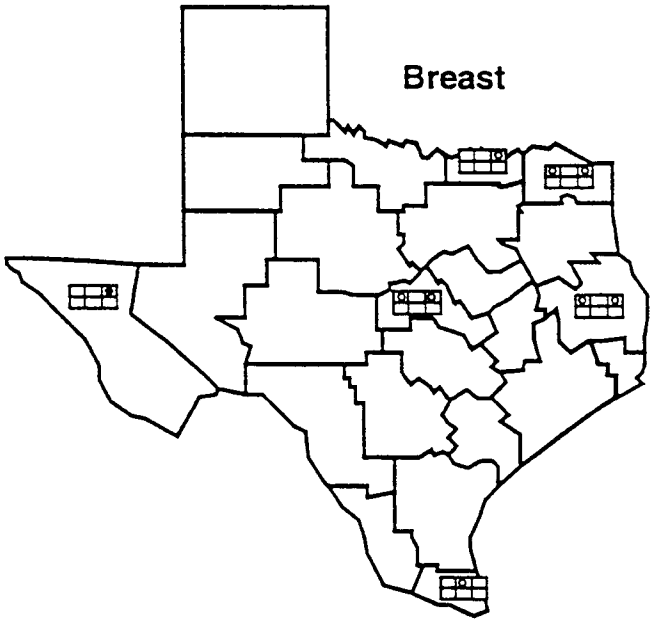
* B = Black, H = Hispanic, W = White/Anglo

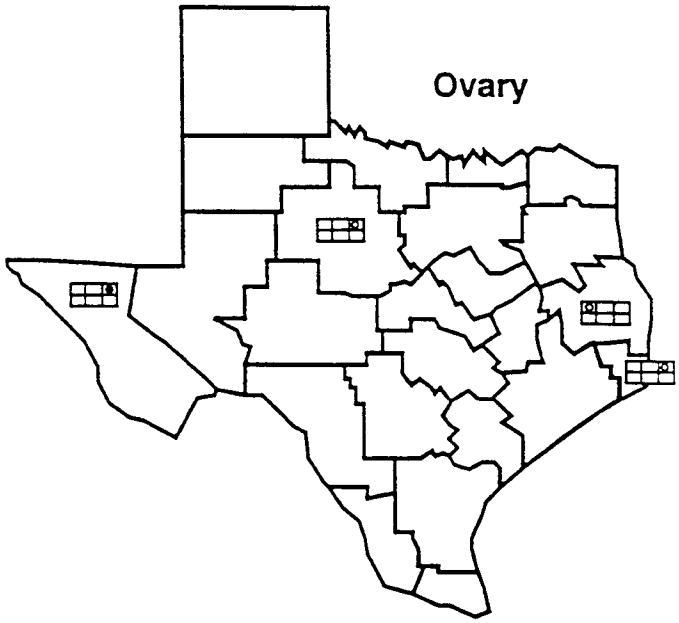
23041154

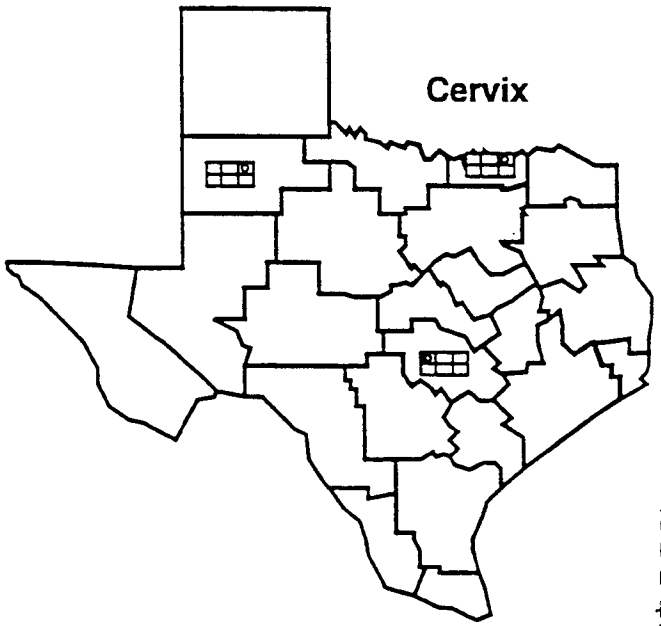
Source: Unpublished data, Cancer Registry Division, Texas Department of Health

FIGURE E-3

Standardized Mortality Ratios (SMRs) Comparing State Planning Regions with the State of Texas by Ethnicity, Sex and Cancer Site, 1980-1991







Legend:

	B	H	W*
Female	●	●	●
Male	●	●	●

SMR ≥ 120, $\alpha < 0.05$ and 12 or more deaths occurred over the 12 yr period

	B	H	W
Female	○	○	○
Male	○	○	○

SMR ≤ 83, $\alpha < 0.05$ and 12 or more deaths occurred over the 12 yr period

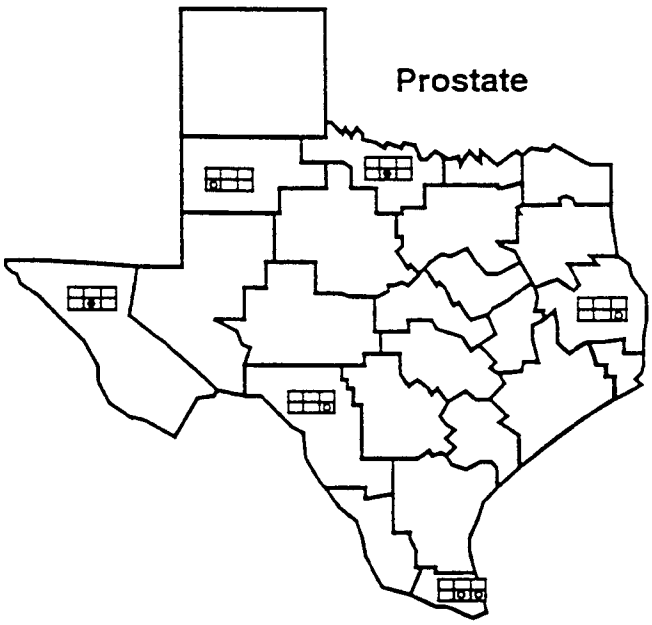
Blank = No qualifying excesses or deficits, or insufficient numbers of deaths

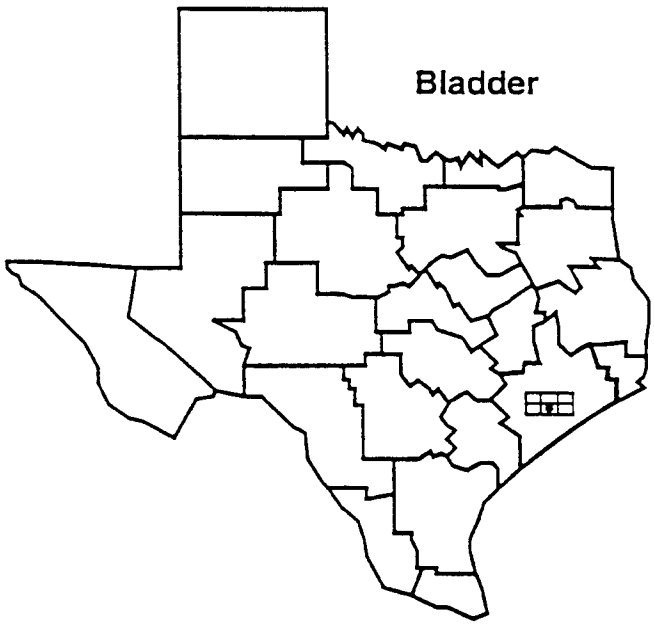
* B = Black, H = Hispanic, W = White/Anglo

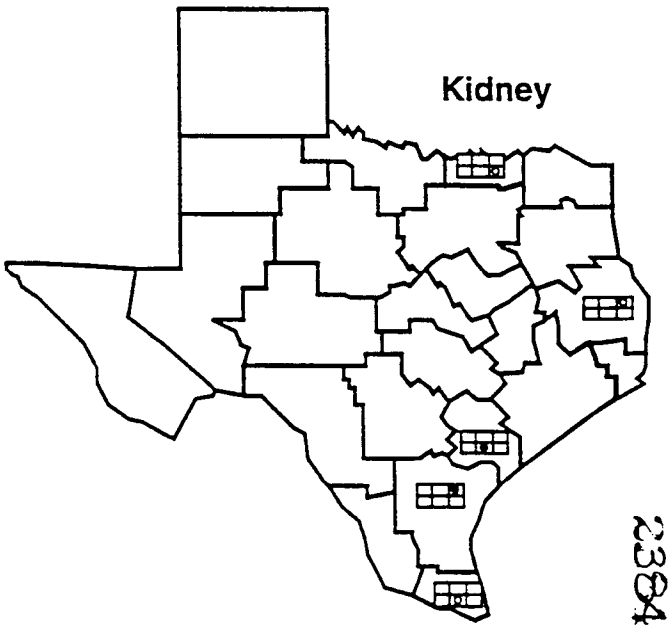
Source: Unpublished data, Cancer Registry Division, Texas Department of Health

FIGURE E-4

Standardized Mortality Ratios (SMRs) Comparing State Planning Regions with the State of Texas by Ethnicity, Sex and Cancer Site, 1980-1991







Legend:

	B	H	W*
Female	●	●	●
Male	●	●	●

SMR ≥ 120, $\alpha < 0.05$ and 12 or more deaths occurred over the 12 yr period

	B	H	W
Female	○	○	○
Male	○	○	○

SMR ≤ 83, $\alpha < 0.05$ and 12 or more deaths occurred over the 12 yr period

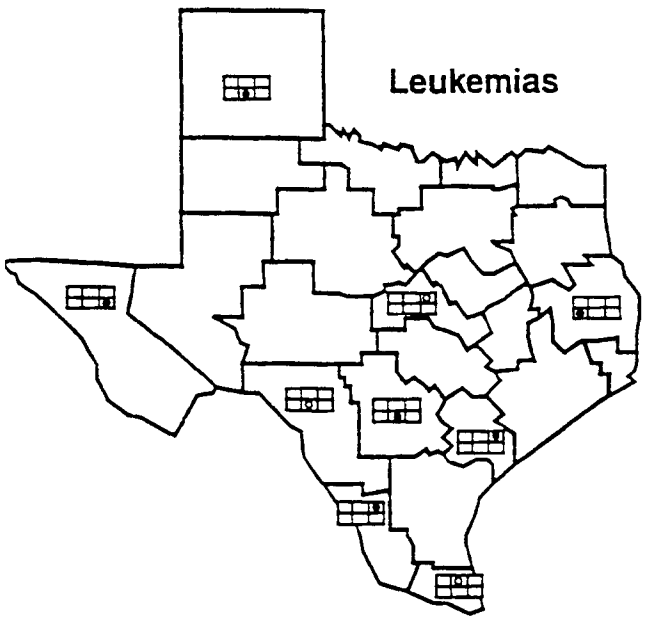
Blank = No qualifying excesses or deficits, or insufficient numbers of deaths

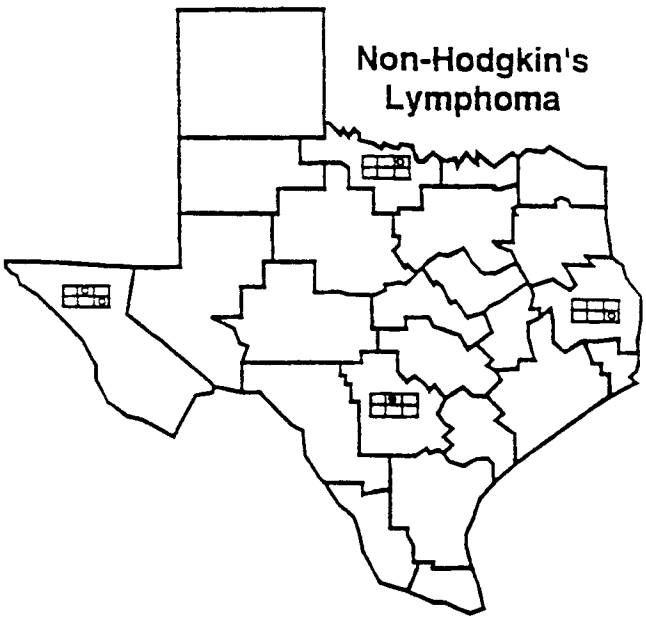
* B = Black, H = Hispanic, W = White/Anglo

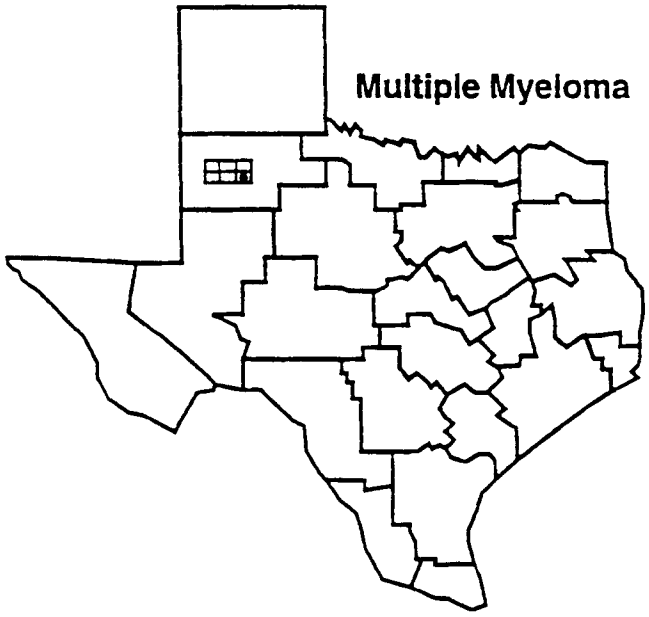
Source: Unpublished data, Cancer Registry Division, Texas Department of Health

FIGURE E-5

Standardized Mortality Ratios (SMRs) Comparing State Planning Regions with the State of Texas by Ethnicity, Sex and Cancer Site, 1980-1991







Legend:

	B	H	W*
Female	●	●	●
Male	●	●	●

SMR ≥ 120, $\alpha < 0.05$ and 12 or more deaths occurred over the 12 yr period

	B	H	W
Female	○	○	○
Male	○	○	○

SMR ≤ 83, $\alpha < 0.05$ and 12 or more deaths occurred over the 12 yr period

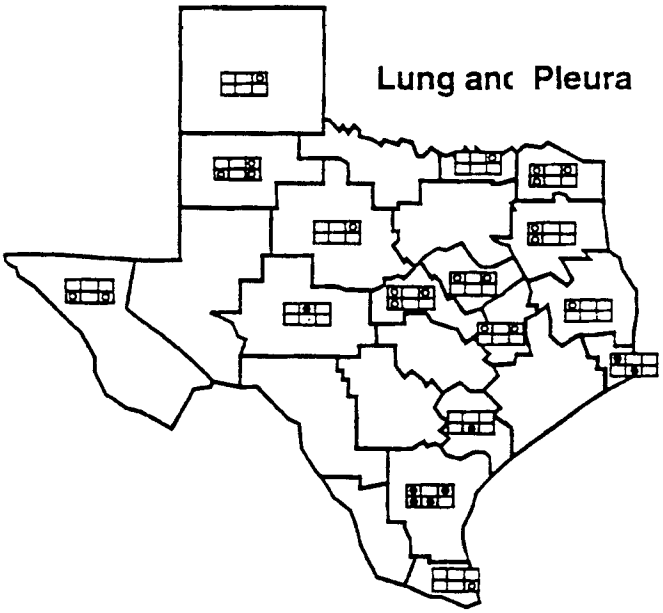
Blank = No qualifying excesses or deficits, or insufficient numbers of deaths

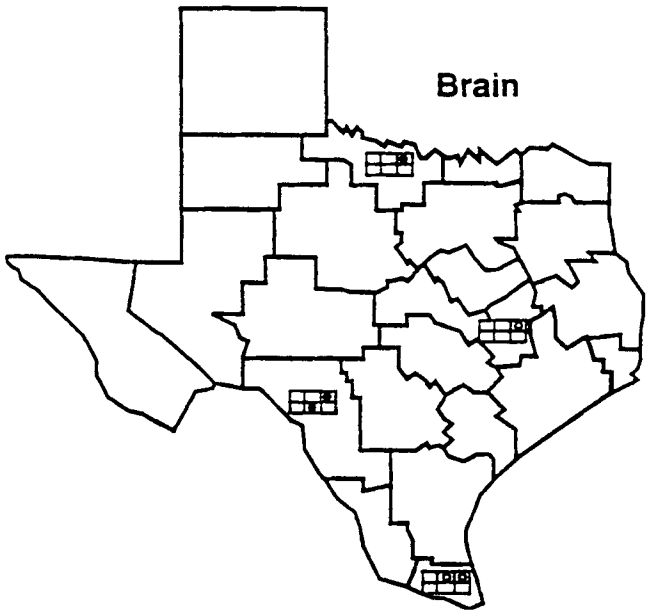
* B = Black, H = Hispanic, W = White/Anglo

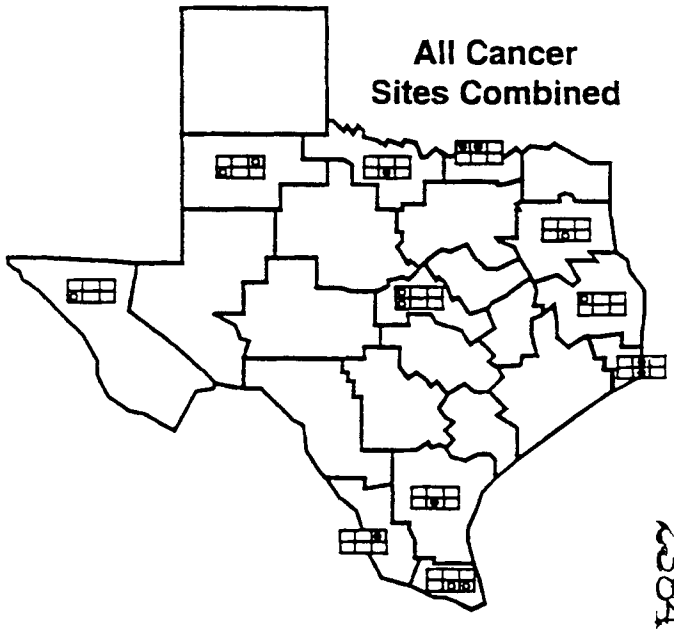
Source: Unpublished data, Cancer Registry Division, Texas Department of Health

FIGURE E-6

Standardized Mortality Ratios (SMRs) Comparing State Planning Regions with the State of Texas by Ethnicity, Sex and Cancer Site, 1980-1991







Legend:

	B	H	W*
Female	●	●	●
Male	●	●	●

SMR ≥ 120 and $\alpha < 0.05$ and 12 or more deaths occurred over the 12 yr period

	B	H	W
Female	○	○	○
Male	○	○	○

SMR ≤ 83 and $\alpha < 0.05$ and 12 or more deaths occurred over the 12 yr period

Blank = No qualifying excesses or deficits, or insufficient numbers of deaths

* B = Black, H = Hispanic, W = White/Anglo

Source: Unpublished data, Cancer Registry Division, Texas Department of Health

Table E-1
The Number of Standardized Mortality Ratios (SMRs) ≥ 120 or ≤ 83
for 17 Cancer Sites with Significant Excessses
or Deficits by Sex, Ethnicity and Region (Councils of Government-COG) for Texas, 1980-1991

COG (Region)		Females			Males			SMRs ≥ 120 or ≤ 83
		Anglo	Black	Hispanic	Anglo	Black	Hispanic	Total ↑ ↓
1	↑	0	0	0	0	0	1	1
	↓	1	0	0	0	0	0	1
	-	15	16	16	15	15	14	
2	↑	0	0	1	1	0	0	2
	↓	4	0	0	1	2	0	7
	-	12	16	15	13	13	15	
3	↑	1	0	0	0	0	1	2
	↓	1	0	0	0	0	0	1
	-	14	16	16	15	15	14	
4	↑	0	0	0	0	0	0	0
	↓	0	0	0	0	0	0	0
	-	16	16	16	15	15	15	
5	↑	0	0	0	0	0	0	0
	↓	2	3	0	0	1	0	6
	-	14	13	16	15	14	15	
6	↑	0	1	0	0	0	0	1
	↓	0	1	0	2	3	0	6
	-	16	14	16	13	12	15	
7	↑	0	0	0	0	0	0	0
	↓	2	0	0	1	0	0	3
	-	14	16	16	14	15	15	

↓	SMR ≤ 83, p < 0.05 and ≥ 12 deaths occurred between 1980-1991
-	No qualifying excess or deficit or insufficient cases for assessment.

COG (Region)		Females			Males			SMRs ≥ 120 or ≤ 83
		Anglo	Black	Hispanic	Anglo	Black	Hispanic	Total ↑ ↓
8	↑	4	0	0	1	0	1	6
	↓	0	0	1	2	1	1	5
	-	12	16	15	12	14	13	
9	↑	1	0	0	0	0	0	1
	↓	0	0	0	1	0	1	2
	-	15	16	16	14	15	14	
10	↑	0	0	2	0	0	0	2
	↓	0	0	0	0	0	0	0
	-	16	16	14	15	15	15	
11	↑	0	0	0	1	1	0	2
	↓	1	1	0	1	1	0	4
	-	15	15	16	13	13	15	
12	↑	0	0	0	0	1	0	1
	↓	0	1	0	0	0	0	1
	-	16	15	16	15	14	15	
13	↑	0	0	0	0	0	0	0
	↓	2	1	0	1	0	0	4
	-	14	15	16	14	15	15	
14	↑	0	0	0	0	1	0	1
	↓	3	3	0	3	0	0	9
	-	13	13	16	12	14	15	
15	↑	1	2	1	0	1	2	7
	↓	1	0	0	0	0	0	1
	-	14	14	15	15	14	13	
16	↑	0	0	0	1	0	1	2
	↓	0	0	1	0	0	1	2
	-	16	16	15	14	15	13	

COG (Region)		Females			Males			SMRs ≥ 120 or ≤ 83
		Anglo	Black	Hispanic	Anglo	Black	Hispanic	Total ↑ ↓
17	↑	1	0	0	2	0	2	5
	↓	0	0	0	0	0	0	0
	-	15	16	16	13	15	13	
18	↑	1	0	5	1	0	5	12
	↓	0	0	0	0	1	0	1
	-	15	16	11	14	14	10	
19	↑	1	0	0	0	0	1	2
	↓	0	0	0	0	0	0	0
	-	15	16	16	15	15	14	
20	↑	2	1	0	0	1	4	8
	↓	0	0	0	0	0	0	0
	-	14	15	16	15	14	11	
21	↑	0	0	0	0	0	0	0
	↓	2	0	6	4	0	6	18
	-	14	16	10	11	15	9	
22	↑	0	0	0	0	0	0	0
	↓	3	0	0	2	0	0	5
	-	13	16	16	13	15	15	
23	↑	0	0	0	0	0	0	0
	↓	4	2	0	0	1	0	7
	-	12	14	16	15	14	16	
24	↑	1	0	0	0	0	1	2
	↓	0	0	0	1	0	2	3
	-	15	16	16	14	15	12	

Table E-2
List of site, sex, race and ethnicity for significant excesses
and deficits by COG (Councils of Government)
for Standardized Mortality Ratios (SMRs) ≥ 120 or ≤ 83
in Texas, 1980-1991

	SMRs ≥ 120 or ≤ 83	SMR	95% CI
COG 1	Excess of Leukemia in Hispanic Males	170	102 - 266
	Deficit of Lung, Pleura in Anglo Females	80	74 - 87
COG 2	Excess of Pancreas in Hispanic Females	158	101 - 235
	Excess of Multiple Myeloma in Anglo Males	134	104 - 171
	Deficit of Rectum in Anglo Females	63	40 - 95
	Deficit of Pancreas in Anglo Females	79	65 - 95
	Deficit of Lung, Pleura in Anglo Males	80	75 - 85
	Deficit of Lung, Pleura in Anglo Females	63	56 - 69
	Deficit of Lung, Pleura in Black Males	65	59 - 95
	Deficit of Cervix in Anglo Females	66	45 - 93
	Deficit of Prostate in Black Males	63	41 - 93
COG 3	Excess of Prostate in Hispanic Males	278	144 - 487
	Excess of Brain in Anglo Females	129	101 - 161
	Deficit of Non-Hodgkin's Lymphoma in Anglo Females	77	60 - 98
COG 4	No cancer sites met significance or selection criteria		
COG 5	Deficit of Large Intestine in Black Females	66	47 - 89
	Deficit of Lung, Pleura in Anglo Females	81	73 - 88
	Deficit of Lung, Pleura in Black Males	78	67 - 90
	Deficit of Lung, Pleura in Black Females	67	50 - 89
	Deficit of Breast in Anglo Females	80	72 - 89
	Deficit of Breast in Black Females	77	59 - 98
COG 6	Excess of Pancreas in Black Females	124	103 - 150
	Deficit of Large Intestine in Black Males	81	67 - 96
	Deficit of Rectum in Anglo Males	77	61 - 97
	Deficit of Liver in Anglo Males	63	47 - 82
	Deficit of Liver in Black Males	59	34 - 94
	Deficit of Lung, Pleura in Black Males	73	67 - 80
	Deficit of Lung, Pleura in Black Females	68	57 - 80
COG 7	Deficit of Liver in Anglo Males	58	38 - 84
	Deficit of Lung, Pleura in Anglo Females	83	77 - 90
	Deficit of Ovary in Anglo Females	83	71 - 97

	SMRs ≥ 120 or ≤ 83	SMR	95% CI
COG 8	Excess of Liver in Anglo Females	170	109 - 253
	Excess of Gallbladder in Anglo Females	170	112 - 248
	Excess of Breast in Anglo Females	122	109 - 135
	Excess of Ovary in Anglo Females	127	105 - 152
	Excess of Prostate in Hispanic Males	142	124 - 163
	Excess of Leukemia in Anglo Males	122	101 - 147
	Deficit of Liver in Hispanic Males	66	48 - 89
	Deficit of Lung, Pleura in Black Males	54	37 - 76
	Deficit of Lung, Pleura in Anglo Males	82	76 - 89
	Deficit of Non-Hodgkin's Lymphoma in Anglo Males	74	55 - 96
	Deficit of Non-Hodgkin's Lymphoma in Hispanic Females	62	44 - 86
COG 9	Excess of Rectum in Anglo Females	143	104 - 191
	Deficit of Large Intestine in Anglo Males	79	69 - 91
	Deficit of Large Intestine in Hispanic Males	52	28 - 87
COG 10	Excess of Large Intestine in Hispanic Females	185	106 - 299
	Excess of Lung, Pleura in Hispanic Females	167	107 - 248
COG 11	Excess of Rectum in Anglo Males	139	106 - 179
	Excess of Liver in Black Males	184	113 - 284
	Deficit of Large Intestine in Black Males	73	53 - 99
	Deficit of Pancreas in Anglo Males	79	66 - 95
	Deficit of Lung, Pleura in Anglo Females	83	76 - 91
	Deficit of Lung, Pleura in Black Females	76	58 - 98
COG 12	Excess of Pancreas in Black Males	146	112 - 188
	Deficit of Cervix in Black Females	57	33 - 91
COG 13	Deficit of Rectum in Anglo Males	58	31 - 99
	Deficit of Lung, Pleura in Anglo Females	72	63 - 83
	Deficit of Lung, Pleura in Black Females	64	45 - 88
	Deficit of Brain in Anglo Females	65	42 - 98
COG 14	Excess of Leukemia in Black Males	145	102 - 201
	Deficit of Large Intestine in Anglo Males	79	70 - 90
	Deficit of Rectum in Anglo Females	65	43 - 96
	Deficit of Lung, Pleura in Black Females	54	40 - 72
	Deficit of Breast in Anglo Females	75	68 - 83
	Deficit of Breast in Black Females	76	59 - 95
	Deficit of Ovary in Black Females	59	33 - 97
	Deficit of Prostate in Anglo Males	81	73 - 91
	Deficit of Kidney in Anglo Females	69	49 - 96
	Deficit of Non-Hodgkin's Lymphoma in Anglo Males	80	65 - 97

	SMRs ≥ 120 or ≤ 83	SMR	95% CI
COG 15	Excess of Stomach in Black Males	135	104 - 172
	Excess of Large Intestine in Hispanic Males	288	161 - 475
	Excess of Large Intestine in Hispanic Females	309	164 - 528
	Excess of Pancreas in Anglo Females	121	104 - 139
	Excess of Pancreas in Black Females	133	103 - 169
	Excess of Lung, Pleura in Black Females	126	107 - 147
	Excess of Lung, Pleura in Hispanic Males	151	102 - 215
	Deficit of Ovary in Anglo Females	80	67 - 95
COG 16	Excess of Liver in Anglo Males	125	111 - 139
	Excess of Bladder in Hispanic Males	144	101 - 198
	Deficit of Stomach in Hispanic Males	82	68 - 99
	Deficit of Stomach in Hispanic Females	78	60 - 99
COG 17	Excess of Stomach in Anglo Males	144	110 - 185
	Excess of Rectum in Anglo Males	185	133 - 251
	Excess of Lung, Pleura in Hispanic Males	130	105 - 161
	Excess of Kidney in Hispanic Males	187	105 - 308
	Excess of Leukemia in Anglo Females	140	111 - 174
COG 18	Excess of Stomach in Hispanic Males	124	109 - 140
	Excess of Stomach in Hispanic Females	120	103 - 140
	Excess of Large Intestine in Hispanic Females	122	107 - 139
	Excess of Large Intestine in Hispanic Males	132	117 - 148
	Excess of Rectum in Hispanic Males	137	107 - 173
	Excess of Liver in Anglo Males	136	115 - 160
	Excess of Liver in Anglo Females	144	116 - 176
	Excess of Liver in Hispanic Males	170	147 - 196
	Excess of Liver in Hispanic Females	150	122 - 182
	Excess of Gallbladder in Hispanic Females	125	103 - 149
	Excess of Non-Hodgkin's Lymphoma in Hispanic Females	122	102 - 145
	Excess of Leukemia in Hispanic Males	125	108 - 144
	Deficit of Stomach in Black Males	68	46 - 97
COG 19	Excess of Gallbladder in Hispanic Males	168	103 - 259
	Excess of Leukemia in Anglo Females	308	172 - 508
COG 20	Excess of Stomach in Hispanic Males	122	101 - 146
	Excess of Large Intestine in Hispanic Males	136	114 - 162
	Excess of Pancreas in Hispanic Males	123	101 - 150
	Excess of Lung, Pleura in Hispanic Males	133	121 - 145
	Excess of Lung, Pleura in Black Females	196	147 - 257
	Excess of Lung, Pleura in Black Males	138	114 - 166
	Excess of Lung, Pleura in Anglo Females	142	131 - 152
	Excess of Kidney in Anglo Females	143	109 - 184

	SMRs ≥ 120 or ≤ 83	SMR	95% CI
COG 21	Deficit of Stomach in Hispanic Males	80	67 - 95
	Deficit of Large Intestine in Anglo Males	80	69 - 92
	Deficit of Large Intestine in Anglo Females	78	67 - 91
	Deficit of Large Intestine in Hispanic Males	46	36 - 58
	Deficit of Large Intestine in Hispanic Females	67	54 - 83
	Deficit of Liver in Hispanic Males	57	42 - 75
	Deficit of Liver in Hispanic Females	64	43 - 90
	Deficit of Gallbladder in Hispanic Males	60	36 - 94
	Deficit of Pancreas in Anglo Males	74	60 - 90
	Deficit of Pancreas in Hispanic Females	70	56 - 85
	Deficit of Lung, Pleura in Anglo Males	75	69 - 80
	Deficit of Breast in Hispanic Females	76	67 - 86
	Deficit of Prostate in Hispanic Males	78	67 - 91
	Deficit of Prostate in Anglo Males	80	70 - 90
	Deficit of Kidney in Hispanic Males	60	43 - 80
	Deficit of Brain in Anglo Females	66	44 - 95
	Deficit of Brain in Hispanic Females	69	47 - 98
	Deficit of Leukemia in Hispanic Females	76	60 - 96
COG 22	Deficit of Pancreas in Anglo Males	79	62 - 99
	Deficit of Kidney in Anglo Males	72	50 - 99
	Deficit of Lung, Pleura in Anglo Females	81	72 - 91
	Deficit of Breast in Anglo Females	80	70 - 90
	Deficit of Cervix in Anglo Females	57	33 - 91
COG 23	Deficit of Pancreas in Anglo Females	75	60 - 93
	Deficit of Lung, Pleura in Anglo Females	71	63 - 79
	Deficit of Lung, Pleura in Black Males	72	57 - 91
	Deficit of Lung, Pleura in Black Females	59	35 - 94
	Deficit of Breast in Anglo Females	77	69 - 87
	Deficit of Breast in Black Females	65	42 - 97
	Deficit of Leukemia in Anglo Females	68	52 - 88
COG 24	Excess of Brain in Anglo Females	180	107 - 284
	Excess of Brain in Hispanic Males	165	101 - 254
	Deficit of Large Intestine in Hispanic Males	65	42 - 96
	Deficit of Prostate in Anglo Males	72	52 - 99
	Deficit of Leukemia in Hispanic Males	55	30 - 92

Table E-3
List of site, sex, race and ethnicity for significant excesses and deficits by COG (Councils of Government) for Standardized Mortality Ratios (SMRs) ≥ 110 or ≤ 91 in Texas, 1980-1991

	SMRs ≥ 110 or ≤ 91	SMR	95% CI
COG 1	Excess of Leukemia in Hispanic Males	170	102 - 266
	Excess of Prostate in Anglo Males	116	106 - 127
	Deficit of Lung, Pleura in Anglo Females	80	74 - 87
	Deficit of Lung, Pleura in Anglo Males	89	84 - 93
COG 2	Excess of Pancreas in Hispanic Females	158	101 - 235
	Excess of Multiple Myeloma in Anglo Males	134	104 - 171
	Deficit of Rectum in Anglo Females	63	40 - 95
	Deficit of Pancreas in Anglo Females	79	65 - 95
	Deficit of Lung, Pleura in Anglo Males	80	75 - 85
	Deficit of Lung, Pleura in Anglo Females	63	56 - 69
	Deficit of Lung, Pleura in Black Males	75	59 - 95
	Deficit of Cervix in Anglo Females	66	45 - 93
	Deficit of Prostate in Black Males	63	41 - 93
	Deficit of Breast in Anglo Females	85	77 - 94
	Deficit of Large Intestine in Anglo Females	84	74 - 95
COG 3	Excess of Prostate in Hispanic Males	278	144 - 487
	Excess of Brain in Anglo Females	129	101 - 161
	Deficit of Non-Hodgkin's Lymphoma in Anglo Females	77	60 - 98
COG 4	Excess of Bladder in Anglo Males	112	104 - 120
	Excess of Rectum in Anglo Females	113	102 - 125
	Excess of Large Intestine in Black Females	112	102 - 122
COG 5	Excess of Lung, Pleura in Anglo Males	111	105 - 117
	Excess of Leukemia in Anglo Males	119	101 - 139
	Deficit of Large Intestine in Black Females	66	47 - 89
	Deficit of Lung, Pleura in Anglo Females	81	73 - 88
	Deficit of Lung, Pleura in Black Males	78	67 - 90
	Deficit of Lung, Pleura in Black Females	67	50 - 89
	Deficit of Breast in Anglo Females	80	72 - 89
	Deficit of Breast in Black Females	77	59 - 98
COG 6	Excess of Pancreas in Black Females	124	103 - 150
	Deficit of Large Intestine in Black Males	81	67 - 96
	Deficit of Large Intestine in Anglo Females	91	84 - 99
	Deficit of Rectum in Anglo Males	77	61 - 97
	Deficit of Liver in Anglo Males	63	47 - 82
	Deficit of Liver in Black Males	59	34 - 94
	Deficit of Lung, Pleura in Black Males	73	67 - 80
	Deficit of Lung, Pleura in Black Females	68	57 - 80
	Deficit of Lung, Pleura in Anglo Females	89	84 - 95
	Deficit of Leukemia in Anglo Females	86	75 - 99

	SMRs ≥ 110 or ≤ 91	SMR	95% CI
COG 7	Deficit of Liver in Anglo Males	58	38 - 84
	Deficit of Lung, Pleura in Anglo Females	83	77 - 90
	Deficit of Ovary in Anglo Females	83	71 - 97
COG 8	Excess of Liver in Anglo Females	170	109 - 253
	Excess of Gallbladder in Anglo Females	170	112 - 248
	Excess of Breast in Anglo Females	122	109 - 135
	Excess of Ovary in Anglo Females	127	105 - 152
	Excess of Prostate in Hispanic Males	142	124 - 163
	Excess of Leukemia in Anglo Males	122	101 - 147
	Excess of Large Intestine in Anglo Females	119	104 - 136
	Deficit of Liver in Hispanic Males	66	48 - 89
	Deficit of Lung, Pleura in Black Males	54	37 - 76
	Deficit of Lung, Pleura in Anglo Males	82	76 - 89
	Deficit of Non-Hodgkin's Lymphoma in Anglo Males	74	55 - 96
	Deficit of Non-Hodgkin's Lymphoma in Hispanic Females	62	44 - 86
COG 9	Excess of Rectum in Anglo Females	143	104 - 191
	Deficit of Large Intestine in Anglo Males	79	69 - 91
	Deficit of Large Intestine in Hispanic Males	52	28 - 87
	Deficit of Prostate in Anglo Males	87	77 - 99
COG 10	Excess of Large Intestine in Hispanic Females	185	106 - 299
	Excess of Lung, Pleura in Hispanic Females	167	107 - 248
COG 11	Excess of Rectum in Anglo Males	139	106 - 179
	Excess of Liver in Black Males	184	113 - 284
	Excess of Large Intestine in Anglo Females	114	102 - 126
	Deficit of Large Intestine in Black Males	73	53 - 99
	Deficit of Pancreas in Anglo Males	79	66 - 95
	Deficit of Lung, Pleura in Anglo Females	83	76 - 91
	Deficit of Lung, Pleura in Black Females	76	58 - 98
COG 12	Excess of Pancreas in Black Males	146	112 - 188
	Deficit of Cervix in Black Females	57	33 - 91
	Deficit of Lung, Pleura in Anglo Males	87	83 - 91
COG 13	Deficit of Rectum in Anglo Males	58	31 - 99
	Deficit of Lung, Pleura in Anglo Females	72	63 - 83
	Deficit of Lung, Pleura in Black Females	64	45 - 88
	Deficit of Brain in Anglo Females	65	42 - 98

	SMRs ≥ 110 or ≤ 91	SMR	95% CI
COG 14	Excess of Leukemia in Black Males	145	102 - 201
	Excess of Lung, Pleura in Anglo Males	112	107 - 118
	Deficit of Large Intestine in Anglo Males	79	70 - 90
	Deficit of Large Intestine in Anglo Females	88	78 - 98
	Deficit of Rectum in Anglo Females	65	43 - 96
	Deficit of Lung, Pleura in Black Females	54	40 - 72
	Deficit of Lung, Pleura in Anglo Females	86	79 - 93
	Deficit of Breast in Anglo Females	75	68 - 83
	Deficit of Breast in Black Females	76	59 - 95
	Deficit of Ovary in Black Females	59	33 - 97
	Deficit of Prostate in Anglo Males	81	73 - 91
	Deficit of Kidney in Anglo Females	69	49 - 96
	Deficit of Non-Hodgkin's Lymphoma in Anglo Males	80	65 - 97
COG 15	Excess of Stomach in Black Males	135	104 - 172
	Excess of Large Intestine in Hispanic Males	288	161 - 475
	Excess of Large Intestine in Hispanic Females	309	164 - 528
	Excess of Pancreas in Anglo Females	121	104 - 139
	Excess of Pancreas in Black Females	133	103 - 169
	Excess of Lung, Pleura in Black Females	126	107 - 147
	Excess of Lung, Pleura in Hispanic Males	151	102 - 215
	Excess of Lung, Pleura in Anglo Males	114	108 - 120
	Excess of Lung, Pleura in Anglo Females	111	103 - 120
	Deficit of Ovary in Anglo Females	80	67 - 95
	Deficit of Breast in Anglo Females	89	81 - 98
COG 16	Excess of Liver in Anglo Males	125	111 - 139
	Excess of Bladder in Hispanic Males	144	101 - 198
	Excess of Stomach in Anglo Females	111	101 - 123
	Excess of Rectum in Anglo Males	113	101 - 126
	Excess of Rectum in the Anglo Females	115	102 - 130
	Excess of Gallbladder in Anglo Females	118	102 - 135
	Excess of Lung, Pleura in Anglo Females	119	115 - 122
	Excess of Lung, Pleura in Black Females	111	103 - 118
	Excess of Breast, in Anglo Females	110	106 - 113
	Excess of Multiple Myeloma in Black Males	119	102 - 137
	Excess of Non-Hodgkin's Lymphoma in Anglo Males	112	105 - 120
	Deficit of Stomach in Hispanic Males	82	68 - 99
	Deficit of Stomach in Hispanic Females	78	60 - 99
COG 17	Excess of Stomach in Anglo Males	144	110 - 185
	Excess of Rectum in Anglo Males	185	133 - 251
	Excess of Lung, Pleura in Hispanic Males	130	105 - 161
	Excess of Kidney in Hispanic Males	187	105 - 308
	Excess of Leukemia in Anglo Females	140	111 - 174
	Excess of Large Intestine in Anglo Males	117	101 - 136
	Deficit of Lung, Pleura in Anglo Females	85	75 - 96

	SMRs ≥ 110 or ≤ 91	SMR	95% CI
COG 18	Excess of Stomach in Hispanic Males	124	109 - 140
	Excess of Stomach in Hispanic Females	120	103 - 140
	Excess of Stomach in Anglo Males	118	105 - 133
	Excess of Large Intestine in Hispanic Females	122	107 - 139
	Excess of Large Intestine in Hispanic Males	132	117 - 148
	Excess of Rectum in Hispanic Males	137	107 - 173
	Excess of Liver in Anglo Males	136	115 - 160
	Excess of Liver in Anglo Females	144	116 - 176
	Excess of Liver in Hispanic Males	170	147 - 196
	Excess of Liver in Hispanic Females	150	122 - 182
	Excess of Gallbladder in Hispanic Females	125	103 - 149
	Excess of Breast in Anglo Females	111	106 - 117
	Excess of Prostate in Anglo Males	112	105 - 119
	Excess of Brain in Anglo Males	114	101 - 128
	Excess of Non-Hodgkin's Lymphoma in Hispanic Females	122	102 - 145
	Excess of Leukemia in Hispanic Males	125	108 - 144
	Deficit of Stomach in Black Males	68	46 - 97
COG 19	Excess of Gallbladder in Hispanic Males	168	103 - 259
	Excess of Leukemia in Anglo Females	308	172 - 508
COG 20	Excess of Stomach in Hispanic Males	122	101 - 146
	Excess of Large Intestine in Hispanic Males	136	114 - 162
	Excess of Pancreas in Hispanic Males	123	101 - 150
	Excess of Lung, Pleura in Anglo Males	117	111 - 124
	Excess of Lung, Pleura in Hispanic Males	133	121 - 145
	Excess of Lung, Pleura in Black Females	196	147 - 257
	Excess of Lung, Pleura in Black Males	138	114 - 166
	Excess of Lung, Pleura in Anglo Females	142	131 - 152
	Excess of Breast in Hispanic Females	116	101 - 132
	Excess of Kidney in Anglo Females	143	109 - 184

	SMRs ≥ 110 or ≤ 91	SMR	95% CI
COG 21	Deficit of Stomach in Hispanic Males	80	67 - 95
	Deficit of Large Intestine in Anglo Males	80	69 - 92
	Deficit of Large Intestine in Anglo Females	78	67 - 91
	Deficit of Large Intestine in Hispanic Males	46	36 - 58
	Deficit of Large Intestine in Hispanic Females	67	54 - 83
	Deficit of Liver in Hispanic Males	57	42 - 75
	Deficit of Liver in Hispanic Females	64	43 - 90
	Deficit of Gallbladder in Hispanic Males	60	36 - 94
	Deficit of Pancreas in Anglo Males	74	60 - 90
	Deficit of Pancreas in Hispanic Females	70	56 - 85
	Deficit of Lung, Pleura in Anglo Males	75	69 - 80
	Deficit of Lung, Pleura in Anglo Females	85	76 - 94
	Deficit of Lung, Pleura in Hispanic Males	85	78 - 92
	Deficit of Lung, Pleura in Hispanic Females	84	73 - 97
	Deficit of Breast in Hispanic Females	76	67 - 86
	Deficit of Prostate in Hispanic Males	78	67 - 91
	Deficit of Prostate in Anglo Males	80	70 - 90
	Deficit of Kidney in Hispanic Males	60	43 - 80
	Deficit of Brain in Anglo Females	66	44 - 95
	Deficit of Brain in Hispanic Females	69	47 - 98
	Deficit of Leukemia in Hispanic Females	76	60 - 96
COG 22	Deficit of Pancreas in Anglo Males	79	62 - 99
	Deficit of Kidney in Anglo Males	72	50 - 99
	Deficit of Lung, Pleura in Anglo Females	81	72 - 91
	Deficit of Breast in Anglo Females	80	70 - 90
	Deficit of Cervix in Anglo Females	57	33 - 91
COG 23	Deficit of Large Intestine in Anglo Females	84	72 - 96
	Deficit of Pancreas in Anglo Females	75	60 - 93
	Deficit of Lung, Pleura in Anglo Males	89	83 - 95
	Deficit of Lung, Pleura in Anglo Females	71	63 - 79
	Deficit of Lung, Pleura in Black Males	72	57 - 91
	Deficit of Lung, Pleura in Black Females	59	35 - 94
	Deficit of Breast in Anglo Females	77	69 - 87
	Deficit of Breast in Black Females	65	42 - 97
	Deficit of Leukemia in Anglo Females	68	52 - 88
COG 24	Excess of Brain in Anglo Females	180	107 - 284
	Excess of Brain in Hispanic Males	165	101 - 254
	Deficit of Large Intestine in Hispanic Males	65	42 - 96
	Deficit of Prostate in Anglo Males	72	52 - 99
	Deficit of Leukemia in Hispanic Males	55	30 - 92