Exhibit 314

Long-Term Follow-up Mortality Study of Petroleum Refinery and Chemical Plant Employees

Shan P. Tsai, PhD, Elizabeth L. Gilstrap, MS, Sally R. Cowles, MD, DrPH, Philip J. Snyder, CIH, MPH, JD, and Charles E. Ross, DO, MS

A previous report presented the 1948–1983 mortality patterns of the Shell Deer Park Manufacturing Complex employees who were employed for at least 3 months from 1948 through 1972. The present study updates the earlier investigation by extending the vital status follow-up through 1989 and by expanding the cohort to include employees hired after 1972. As in the previous study, the overall mortality and cancer mortality for both refinery and chemical employees were quite favorable compared to residents in the local population. Among refinery workers, cancers for which a suspicion of work-relatedness was raised in the previous study, i.e. leukemia and cancers of the central nervous system and biliary passage/liver, no supportive evidence was found in this update. For both refinery and chemical plant employees, the mortality rate due to cancers of all lymphopoietic tissue increased with increasing duration of employment; this finding was also noted by the original study. This was also evident for lymphoreticulosarcoma in refinery employees and for leukemia in chemical plant employees. However, elevations of cancers of all lymphatic and hematopoietic tissue are primarily confined to employees who started work at the complex before 1946. By contrast, deaths from cancer of all lymphatic and hematopoietic tissue for employees hired after 1945 were 22% lower than the comparison population. Seven deaths with mesothelioma mentioned on the death certificates were identified, with 3.2 deaths expected, resulting in a statistically nonsignificant SMR of 219.

KEY WORDS: petroleum, chemical industry, cohort study, occupational cancer

INTRODUCTION

This report describes the mortality experience of employees of the Shell Deer Park Manufacturing Complex (DPMC) over a period of 42 years, 1948–1989. The study population consists of 9,720 employees who had potential plant exposure and who worked at least 3 months at this facility during the follow-up period. In 1984, a cohort mortality study of this facility which included 6,831 employees was conducted by Marsh and colleagues of the University of Pittsburgh [Marsh et al., 1991]. The results of that study indicated that the overall mortality of these employees was low compared to that of the local county (Harris County, TX) population. There were no statistically significant excesses of death from any cause. In the earlier study, the standardized mortality ratio of cancers of all lymphopoietic tissue, however, was statistically increased with increasing duration of employment. Patterns of increased mortality risk were also observed among refinery workers for leukemia and cancers of the central nervous system and biliary passages/liver.

The purpose of this study was to update the earlier investigation by extending the vital status follow-up through 1989, and by expanding the cohort to include employees hired after 1972. The increased size of the study population and the additional 6 years of follow-up add sub-

Corporate Medical Department, Shell Oil Company, Houston, TX.
Address reprint requests to Dr. Shan P. Tsai, Corporate Medical Department, Shell Oil Company, P. O. Box 2463, Houston, TX 77252-2463

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stantial power to the original cohort to determine whether the above findings at DPMC have persisted. In addition, there have been inconsistent reports in the literature of increased mortality for various cancers including kidney, malignant melanoma, stomach, and lung in petroleum industry employees [Wong and Raabe, 1989; Delzell et al., 1988; Harrington, 1987]. With this extended cohort, further evaluations can be made to determine whether such reported mortality risks are present among DPMC employees.

Refinery operations at Deer Park started in 1929 with approximately 500 employees. In December 1940, the construction of the chemical division began. By 1941, there were 55 people assigned to the chemical division, including many who were transferred from the refinery. Operations expanded significantly during the 1946–1952 period. During the past 60 years, numerous operations changes have occurred at both the refinery and chemical plant. New units have been added, processes at existing units have changed, and some units have been shut down or sold (e.g. vinyl chloride production). Patterns of potential chemical exposure are also likely to have changed over the years, due to varying use of non-plant maintenance contractors and to changes in work practices. The complex is now one of the larger oil refinery/petrochemical plants in the United States. It refines crude oil and manufactures various fuels, oil lubricants, and petrochemicals such as benzene, toluene, isopropyl alcohol, epichlorohydrin, butadiene, and epoxy resins. Other potentially hazardous substances found at the facility include hydrogen sulfide, polynuclear aromatics, asbestos, and various solvents. Currently, there are more than 2,400 employees working at the complex.

MATERIALS AND METHODS

Cohort Definition and Data Collection

The cohort was studied for the period 1948–1989. The study population included all hourly production and maintenance employees, as well as all salaried employees with routine field or laboratory assignments, employed at least 3 cumulative months at DPMC between January 1, 1948 and December 31, 1989. Those who died or who left the company before 1948 were not included. Salaried employees included foremen, first-line supervisors, chemists, laboratory technicians, and certain engineering, quality control, and security personnel.

The original cohort (n = 6,831) studied by Marsh et al. included individuals with 3 or more months of employment at DPMC from 1948 through 1972 and was developed from company personnel and payroll records that provided demographic and work history information. In the previous study, a second cohort (n = 2,593) was also established, but not analyzed, which included employees hired from January 1, 1973 through December 31, 1981 using otherwise identical eligibility criteria. Work histories and vital status of this second cohort were ascertained through December 31, 1983. This cohort was assembled on the expectation that it would be included in the next update. In addition to this group, all new employees hired from January 1, 1982 to December 31, 1989 who met the eligibility criteria were included in this current update. A total of 9,720 employees were identified for this update study.

Source documents for the previous study included work history and personnel records retrieved from the plant for 1948–1976, and computerized records from the Shell Personnel Processing System (SPPS), which contains demographic and work history records for all employees from 1973 forward. For this study update, one individual coded name, employee number, and social security number (SSN) as the primary demographic variables from the work history record. The remaining variables (e.g., sex, race, date of birth, date of hire, date of termination, date of death) were retrieved from SPPS. Cohort members' work histories were brought up to date through 1989 and were coded using an updated version of the original study's coding manual. The job classification codes in this manual were developed by Shell industrial hygienists and were updated through 1990. The work histories, which were derived from the SPPS computerized records, were newly coded or updated by three trained coders (including a former DPMC employee involved with the original study).

The participants in the study cohort were subdivided into two main subcohorts based on primary work location on the refinery or chemical plant side of the DPMC. The cohort members were assigned to either refinery or chemical plant based on the location in which the individual had worked longest. This was considered reasonable for two reasons. First, in 1985, an administrative change at DPMC consolidated the refinery and chemical codes into a single code, so that for those work history jobs with no specific department listed (i.e., many maintenance jobs), there could be no differentiation for location. Also, most employees had worked almost exclusively at one of the two locations until that date. Of the 2,101 employees coded as having mixed refinery and chemical plant experience, the reassigned codes were distributed almost equally, with 46% assigned to refinery and 53% to the chemical plant. The 16 employees who defied classification after this assignment (primarily those hired after 1985) were included in the refinery group.

Data Quality Control

Quality control procedures were followed for this update. At the initiation of work history coding for all individuals with surname beginning A through C (24%) work history records were independently double-coded, checked, and edited for errors. This procedure was carried out to ensure that all coders were consistently interpreting the coding manual and coding the data correctly from the beginning. The data were computerized and programs were run to identify errors. Afterward, a 5% systematic random sample of those work histories not double coded were included in a coding reliability check. The code sheet was checked with the original source document, the hard copy work history record, and errors were counted per variable, not per record, with a 2% overall error rate for the three coders. This 5% sample was also used to check the demographic coding; the overall error rate for this coding was 0.07%.

Data entry screens similar to the data abstraction forms were used for computer entry. Data ranges for individual variables on each screen were limited to further reduce the possibility of error. One data entry operator was responsible for key entry of both the demographic and work history records. A 10% systematic random sample was used for a data entry reliability check with errors counted per variable. Error rates for the data entry of demographic and work history records were 0.12% and 0.07%, respectively.

Vital Status Follow-up

Vital status as of December 31, 1989 for each study member was determined from a number of sources, including company records, the Social Security Administration's (SSA) Master Beneficiary record file, and the National Death Index (NDI). A total of 2,498 employees were actively employed at DPMC as of December 31, 1989, and were classified as living. Persons who were presumed living as of December 31, 1983, the end of the previous study, were again classified as presumed living as of December 31, 1989 if no death record was found from the vital status sources. Those persons with unknown vital status at the end of the previous study (n = 136), were classified as lost-to follow-up unless a death record was identified. Those employees who terminated after December 31, 1983 and who were not identified by the SSA search or the NDI search were assumed to be alive.

For deceased employees, death certificates were obtained, when available, from company benefits files. Death certificates for those potential decedents identified by the SSA and/or NDI were requested from the respective state vital statistics departments and verified with company information to ensure a correct match between these records. The underlying cause of death was coded independently by two Shell nosologists trained by the National Center for Health Statistics according to rules of the International Classification of Diseases (ICD) in effect at the time of death and according to the eighth revision of the ICD. Discrepancies with underlying cause of death coding (4.9%) were reviewed and coded by a third independent nosologist. The three nosologists met and concurred on the correct ICD codes. There was 100% verification of the death certificate data entry.

Statistical Methods

An employee entered the follow-up period on April 1, 1948, if this person began employment before 1948. Otherwise, he or she entered the study three months after the start of employment at DPMC. Person-years were accumulated from the entry date to the date of death, the study end date, or the date of loss to follow-up, whichever came first.

The mortality experience for selected causes is expressed as standardized mortality ratios (SMRs). The SMR is the most commonly used summary index for assessing mortality risk in a cohort study [Tsai and Wen, 1986]. The actual computations were conducted with the Occupational Cohort Mortality Analysis Program (OCMAP), using the ICD revision in effect at the time of death [Marsh and Preininger, 1980]. The SMR is the number of observed deaths in the study group divided by the number of deaths that would be expected (×100) if the death rates for a comparison population were experienced. The number of deaths expected is adjusted for age and race of the study population and for the time period during which the follow-up takes place. Like the previous study, those employees with unknown race (n = 2,892) were included as white for statistical analyses. In addition, to help control for geographic variations in mortality, the death rates for Harris County, Texas, the county in which the study population largely resided, were used as the comparison.

The source for county mortality rates from the Mortality and Population Data System (MPDS) includes cancer rates for 1950–1989 [Marsh et al., 1987]. For the period 1948–1949, expected cancer deaths were calculated based on 1950–1954 rates. The noncancer MPDS comparison mortality rates include 1962–1989, and the 1962–1964 rates were applied to calculate rates for 1948–1959. The 95% confidence interval for each SMR was calculated and its deviation from 100 was tested assuming a Poisson distribution for the observed deaths, using a two-sided test of significance [Bailar and Ederer, 1964]. Those deaths for which no death certificate (n = 47) was ascertained were included in the overall causes, but not in the specific causes. The chi-square trend statistic was used to test for linear trends in SMRs relative to duration of employment [Breslow et al., 1983].

RESULTS

A total of 9,720 employees who satisfied the cohort criteria are included in this report. They contributed 246,656 person-years during the 42-year observation period. The 6-year update added 2,889 new employees and 64,873 person-years. Average years of follow-up were approximately 26 years for male employees, and 15 years for female employees. The vital status for 53% of the cohort was determined from company records. A third of the re-

TABLE I. Distribution of Deer Park Study Population by Sex, Race, and Work Area[a]

Sex/race	Refinery n	Refinery %	Chemical plant n	Chemical plant %	Total n	Total %
Male	5,019	90.8	3,988	95.1	9,007	92.7
White	4,444	(88.5)	3,613	(90.6)	8,057	(89.5)
Nonwhite	575	(11.5)	375	(9.4)	950	(10.5)
Female	508	9.2	205	4.9	713	7.3
White	427	(84.1)	176	(85.9)	603	(84.6)
Nonwhite	81	(15.9)	29	(14.1)	110	(15.4)
Total	5,527	100.0	4,193	100.0	9,720	100.0

[a]Assignment by longest location worked.

tired employees were deceased as of the closing date of the study. Among 4,536 employees who left employment, 686 were identified as deceased as of December 31, 1989, and 128 were lost to follow-up (1% of the total study population). Death certificates were obtained for 1,705 or 97.3% of the 1,752 identified deaths.

Table I shows the distribution of the total cohort by sex, race, and work area. The distribution by year of hire is presented in Table II. A third of the cohort members were hired before 1950, thus, having a potential follow-up of up to 40 years. Seventy-six percent (76%) of the refinery employees and 93% of the chemical plant employees were hired after 1945. More than two-thirds of the cohort members were under 30 years of age when they entered the study. Among men, about 62% of the refinery employees and 53% of the chemical plant employees worked at DPMC for at least 10 years, in contrast to approximately 40% of women.

Table III shows the observed deaths, SMRs, and their 95% confidence intervals (CI) by selected causes of death for refinery, chemical plant, and the total cohort among male employees. For the refinery, chemical plant, and total employees, the overall mortality during the period 1948–1989 was significantly lower than the corresponding Harris County population with SMRs of 79 (95% CI = 75–84), 62 (95% CI = 57–68), and 73 (95% CI = 70–77), respectively. SMRs for all cancer were also significantly lower than the Harris County experience with an SMR of 86 (77–96) for refinery employees and 78 (66–92) for chemical plant employees. Both lung cancer (SMR = 75, 64–87) and nonmalignant respiratory disease (SMR = 68, 55–83) were significantly lower than the comparison population. Statistically significant deficits were also seen for several other causes of death among male employees in this complex including diabetes, cerebrovascular disease, heart disease, accidents, suicides, and homicides. Of more than 60 causes of death examined, none showed a statistically significant increase.

The SMR for cancer of several sites showed a nonsignificant increase. Notable among refinery employees were cancers of the lymphatic and hematopoietic tissue (SMR = 122; 87–167), including lymphosarcoma and reticulosarcoma (SMR = 170; 77–322) and Hodgkin's disease (SMR = 137; 37–351). Among the chemical plant employees, malignant melanoma of the skin (SMR = 126; 41–294) and cancer of the other lymphatic tissue (SMR = 137; 63–260), which includes multiple myeloma, polycythemia vera, and other lymphoma, were increased. There was no increase in cancers of the kidney, the central nervous system, or biliary passages and liver.

Seven deaths with mesothelioma mentioned on the death certificates were identified by reviewing all death certificates. The expected number of deaths cannot be estimated directly because mortality rates in the general population are not available for this cause of death. Using mesothelioma incidence rates for 1973–1988 from the Surveillance, Epidemiology, and End-Results (SEER) Program of the National Cancer Institute (unpublished data), 3.2 expected deaths were estimated, resulting in an elevated but statistically nonsignificant SMR of 219 (88–452).

Only 15 deaths occurred among 713 female employees in the cohort, resulting in an SMR of 49 (28–81) for all causes of death combined. Six cancer deaths were observed while 9 deaths were expected (SMR = 66; 24–143). Cancer of the lymphatic and hematopoietic tissue was increased, but was not statistically significant, based on three observed deaths (SMR = 369; 76–1079). Two cases of respiratory system cancer were noted with 1.8 expected. There was only one observed breast cancer death, while two such deaths were expected (SMR = 45; 1–250). The numbers of deaths for these causes were small, thus giving fairly unstable estimates as illustrated by the wide confidence intervals.

Mortality patterns by duration of employment for male refinery employees are presented in Table IV. Analyses were limited to those cancer sites with five or more observed deaths to enable some assessment of mortality

TABLE II. Distribution of Deer Park Study Population by Year of Hire, Work Area, and Sex

	Refinery				Chemical plant				Total			
	Male		Female		Male		Female		Male		Female	
Year of hire	n	%	n	%	n	%	n	%	n	%	n	%
Before 1930	173	3.5	0	0.0	4	0.1	0	0.0	177	2.0	0	0.0
1930–1939	434	8.7	0	0.0	66	1.7	0	0.0	500	5.6	0	0.0
1940–1945	617	12.3	27	5.3	228	5.7	7	3.4	845	9.4	34	4.8
1946–1949	925	18.4	6	1.2	784	19.7	3	1.4	1,709	19.0	9	1.3
1950–1959	1020	20.3	25	4.9	1,046	26.2	10	4.9	2,066	22.9	35	4.9
1960–1969	415	8.3	32	6.3	442	11.1	10	4.9	857	9.5	42	5.9
1970–1979	1101	21.9	317	62.4	1,182	29.6	127	62.0	2,283	25.3	444	62.3
1980–1989	334	6.7	101	19.9	236	5.9	48	23.4	570	6.3	149	20.9
Total	5,019	100.1	508	100.0	3,988	100.0	205	100.0	9,007	100.0	713	100.1

trends. It is interesting to note that the SMRs for the majority of the causes, including cancer of the kidney and biliary passages and liver, exhibit a "V" shape, i.e., the SMR is the lowest in the intermediate employment duration group (20–29 years) than in the other two extreme groups. For cancer of the lymphatic and hematopoietic tissue and its subclassifications, including lymphoreticulosarcoma and other lymphopoietic tissue, SMRs are higher for longer duration of employment groups. The trends with length of employment for these causes are statistically significant. There were no noticeable trends for cancer of the central nervous system or leukemia.

Table V presents mortality patterns by employment duration for male chemical plant employees for selected causes of death. In contrast to the refinery employees, the intermediate employment group had the highest SMR for overall cancer (SMR = 86). This pattern is also true for cancer of the respiratory system. For cancer of the lymphatic and hematopoietic tissue, findings are similar to those of refinery employees. The increasing pattern is also noted for deaths due to cancer of the pancreas. In addition, SMRs for cancer of the buccal cavity and pharynx and leukemia are higher for longer duration of employment groups.

Since the chemical plant was brought online from 1945–1950 and several refinery units were either built or modified after 1945, an analysis was conducted on a subcohort of male employees who were hired on or after January 1, 1946 as being most representative for the current workforce. Three-fourths (n = 3,795) of the refinery employees and more than 92% of the chemical plant employees (n = 3,690) were hired since that date. The average years of follow-up were approximately 25 years with nearly 13 years average length of employment.

The results for this group are presented in Table VI. There were 868 observed deaths among persons hired after 1945. The mortality for all causes of death was significantly lower for both refinery (SMR = 73; 67–79) and chemical plant (SMR = 59; 53–66) groups. The observed cancer deaths were also significantly lower than those of the expected. Slight, but not significant, elevations in mortality were seen for a number of cancer sites; notable ones were cancer of the kidney (5 cases) among refinery employees (SMR = 131; 42–305) and leukemia (7 cases) among chemical plant employees (SMR = 129; 52–265). There was only one death from cancer of the biliary passages and liver, with 3.8 expected among refinery employees. Cancer of the lung was significantly lower among persons hired after 1945, regardless of where they worked. SMRs for cancer of the lymphatic and hematopoietic tissue were also lower than expected. The observed numbers of death for cancer of the central nervous system were about the same as the numbers expected for both refinery and chemical plant employees. For noncancer disease categories, the observed numbers of death are appreciably lower than expected, with SMRs ranging from 34 for homicides to 73 for cerebrovascular disease.

DISCUSSION

Numerous epidemiologic studies of petroleum workers have been conducted during the past 15 years [Hanis et al., 1979, 1982, 1985a,b; Thomas et al., 1982, 1984; Wen et al., 1981, 1983a, 1984a,b, 1985, 1986; Rushton and Alderson, 1981a,b, 1983; Schottenfeld et al., 1981; Reeve et al., 1982; Tsai et al., 1983; Austin and Schnatter, 1983; Savitz and Moure, 1984; McCraw et al., 1985; Divine et al., 1985; Divine and Barron, 1986, 1987; Kaplan, 1986; Wong et al., 1986; Thériault and Provencher, 1987; Nelson et al., 1987; Delzell et al., 1988, Wongsrichanalai et al., 1989; Wong and Raabe, 1989; Marsh et al., 1991, Shallenberger et al., 1992; Dagg et al., 1992; Tsai et al., 1993]. Most of the studies

TABLE III. Observed Numbers of Deaths (OBS) and Standardized Mortality Ratios (SMR)[a] by Cause and Work Area, 1948–1989, for Deer Park Male Study Population

	Refinery (n = 5,019) 133363.5 person-years			Chemical plant (n = 3,988) 102653.1 person-years			Total (n = 9,007) 236018.7 person-years		
Cause of death (8th ICD revision)	OBS	SMR	95% CI[b]	OBS	SMR	95% CI	OBS	SMR	95% CI
All causes of death (001–999.8)	1,225	79.1	75–84	512	62.2	57–68	1,737	73.2	70–77
All malignant neoplasms (140–209)	306	86.1	77–96	150	78.1	66–92	456	83.3	76–91
Buccal cavity and pharynx (140–149)	7	62.8	25–129	6	101.4	37–221	13	76.2	41–130
Digestive organs and peritoneum (150–159)	70	83.1	65–105	27	62.7	41–92	97	76.2	62–93
Esophagus (150)	7	78.7	32–162	1	21.4	.5–119	8	58.9	25–116
Stomach (151)	12	92.9	48–162	2	33.8	4–122	14	74.3	41–125
Large Intestine (153)	25	92.1	60–136	11	76.1	38–136	36	86.5	61–120
Rectum (154)	7	117.8	47–243	1	32.1	1–179	8	88.3	38–174
Biliary passages and liver primary (155,156)	7	80.4	32–166	3	66.9	14–195	10	75.8	36–139
Pancreas (157)	10	55.9	27–103	8	87.9	38–173	18	66.7	39–105
Respiratory system (160–163)	112	77.1	63–93	59	73.0	56–94	171	75.6	65–88
Bronchus, trachea, lung (162)	107	76.7	63–93	56	72.1	54–94	163	75.1	64–87
Prostate (185)	23	95.8	61–144	10	101.6	49–187	33	97.5	67–137
Kidney (189.0,189.1,189.2)	7	85.0	34–175	4	85.7	23–219	11	85.2	43–152
Bladder and other urinary organs (188,189.9)	4	52.9	14–135	1	32.3	1–180	5	46.9	15–109
Malignant melanoma of skin (172.0–172.4,172.6–172.9)	4	69.6	19–178	5	126.0	41–294	9	92.6	42–176
Central nervous system (191,192)	10	102.0	49–187	5	79.3	26–185	15	93.1	52–153
All lymphatic and hematopoietic tissue (200–209)	39	122.0	87–167	17	92.3	54–148	56	111.2	84–144
Lymphosarcoma and reticulosarcoma (200)	9	169.5	77–322	1	34.7	1–194	10	122.1	59–225
Hodgkin's disease (201)	4	137.0	37–351	0	—	—	4	84.2	23–215
Leukemia and aleukemia (204–207)	14	109.4	60–184	7	98.3	39–202	21	105.4	65–161
All other lymphopoietic tissue (residual)	12	109.8	57–192	9	136.9	63–260	21	120.0	74–183
Diabetes mellitus (250)	12	67.9	35–119	2	22.2	3–80	14	52.5	29–88
Cerebrovascular disease (430–438)	53	60.3	45–79	27	74.9	49–109	80	64.5	51–80
All heart disease (390–8,400.1,400.9,402, 404,410–4,420–9)	472	80.1	73–88	177	61.2	52–71	649	73.9	68–80
Nonmalignant respiratory disease (460–519)	66	68.9	53–88	28	64.7	43–93	94	67.6	55–83
Cirrhosis of liver (571)	21	47.8	30–73	10	36.3	17–67	31	43.3	29–61
Accidents (800–949)	92	91.2	74–112	41	57.1	41–77	133	77.0	64–91
Suicides (950–959)	30	74.3	50–106	9	30.3	14–58	39	55.7	40–76
Homicides and other External causes (residual)	16	36.9	21–60	8	23.3	10–46	24	30.9	20–46
Unknown causes of death (999.9)	39	—	—	8	—	—	47	—	—

[a]Expected numbers of death based on Harris County population, ICD Revision in effect at time of death.
[b]95% confidence interval.

have combined workers from refinery and chemical operations and have not examined them separately. Potential exposures and some of the demographic characteristics can be quite different between these two groups. In this study, we have examined the mortality experience of a large refinery and chemical complex by individual plant operations, as well as the total combined group.

The overall mortality rate for this complex was significantly lower than that expected based on the experience of local residents in Harris County, Texas. The total study population during the 42-year follow-up period exhibited 27% lower overall mortality and 17% lower cancer mortality. The favorable overall mortality experience of this cohort is comparable to what has been reported in other large petroleum and petrochemical populations [Delzell et al., 1988; Wong and Raabe, 1989]. This phenomenon has been referred to as the "healthy worker effect," which can be attributed to a number of factors [Fox and Collier, 1976; Ott et al., 1976; Wen et al., 1983b; Monson, 1986]. The selection of relatively healthy individuals into the workforce plays an important role. The positive socioeconomic effects of continuing employment with its many benefits including

TABLE IV. Cancer Mortality Experience of Male Refinery Population by Duration of Employment, 1948–1989

Cancer site		Duration of employment (yr) Under 20	20–29	30+	Trend test p-value
All malignant neoplasms	OBS[a]	136	85	85	
	SMR	86.6	72.9	103.9	n.s.[c]
		(73–102)[b]	(58–90)	(83–128)	
Buccal cavity and pharynx	OBS	3	4	0	
	SMR	59.1	108.0	—	—[d]
		(12–173)	(29–276)	—	
Digestive organs	OBS	35	19	16	
	SMR	93.5	68.3	84.2	n.s.
		(65–130)	(41–107)	(48–137)	
Esophagus	OBS	6	0	1	
	SMR	140.1	—	52.1	—
		(51–305)	—	(1–290)	
Stomach	OBS	8	2	2	
	SMR	128.2	46.9	83.1	n.s.
		(55–253)	(6–169)	10–300	
Large intestine	OBS	8	10	7	
	SMR	70.3	111.0	103.8	n.s.
		(30–138)	(53–204)	(42–214)	
Rectum	OBS	6	1	0	
	SMR	222.4	50.9	—	—
		(82–484)	(1–283)	—	
Biliary/liver	OBS	3	1	3	
	SMR	79.8	34.6	146.1	n.s.
		(16–233)	(1–193)	(30–427)	
Pancreas	OBS	3	4	3	
	SMR	39.4	65.3	72.2	n.s.
		(8–115)	(18–167)	(15–211)	
Respiratory system	OBS	55	29	28	
	SMR	88.3	60.2	80.3	n.s.
		(66–115)	(40–86)	(53–116)	
Prostate	OBS	9	7	7	
	SMR	103.5	78.7	109.3	n.s.
		(47–196)	(32–162)	(44–225)	
Kidney	OBS	3	1	3	
	SMR	83.9	37.0	153.4	n.s.
		(17–245)	(1–206)	(32–448)	
Central nervous system	OBS	5	3	2	
	SMR	100.3	102.2	106.2	n.s.
		(32–234)	(21–299)	(13–384)	
All lymphopoietic tissue	OBS	12	12	15	
	SMR	76.8	123.3	227.3	0.004
		(40–134)	(64–215)	(127–375)	
Lymphoreticulosarcoma	OBS	2	1	6	
	SMR	74.4	57.7	675.1	0.002
		(9–269)	(1–322)	(248–1,469)	
Leukemia	OBS	6	5	3	
	SMR	98.1	124.7	112.3	n.s.
		(36–214)	(40–291)	(23–328)	
Other lymphopoietic (residual)	OBS	3	4	5	
	SMR	60.7	121.8	184.9	0.11
		(12–177)	(33–312)	(60–432)	

[a]Observed deaths.
[b]95% confidence interval.
[c]Not significant.
[d]Trend test not possible with this grouping.

TABLE V. Cancer Mortality Experience of Male Chemical Plant Population by Duration of Employment, 1948–1989

Cancer site		Duration of employment (yr) Under 20	20–29	30+	Trend test p-value
All malignant neoplasms	OBS[a]	90	40	20	
	SMR	74.2	86.1	83.0	n.s.[c]
		(60–91)[b]	(61–117)	(51–128)	
Buccal cavity and pharynx	OBS	3	2	1	
	SMR	79.2	139.5	144.5	n.s.
		(16–231)	(17–504)	(4–805)	
Digestive organs	OBS	14	8	5	
	SMR	51.4	77.1	91.9	n.s.
		(28–86)	(33–152)	(30–214)	
Large intestine	OBS	6	3	2	
	SMR	67.1	85.5	99.5	n.s.
		(25–146)	(18–250)	(12–359)	
Pancreas	OBS	4	2	2	
	SMR	70.6	87.5	174.4	0.33
		(19–181)	(11–316)	(21–630)	
Respiratory system	OBS	36	16	7	
	SMR	72.7	77.9	65.3	n.s.
		(51–101)	(44–126)	(26–135)	
Prostate	OBS	7	2	1	
	SMR	127.8	68.3	69.6	n.s.
		(51–263)	(8–247)	(2–388)	
Malignant melanoma skin	OBS	4	1	0	
	SMR	135.7	142.2	—	—[d]
		(37–347)	(4–792)	—	
Central nervous system	OBS	5	0	0	
	SMR	114.8	—	—	—
		(37–268)	—	—	
All lymphopoietic tissue	OBS	7	6	4	
	SMR	55.5	157.9	203.1	0.01
		(22–114)	(58–344)	(55–520)	
Leukemia	OBS	2	3	2	
	SMR	41.0	199.4	272.3	0.02
		(5–148)	(41–583)	(33–984)	
Other lymphopoietic (residual)	OBS	4	3	2	
	SMR	96.7	202.1	210.1	0.28
		(26–248)	(42–591)	(25–759)	

[a]Observed deaths.
[b]95% confidence interval.
[c]Not significant.
[d]Trend test not possible with this grouping.

comprehensive health insurance may also contribute. In addition, even though the proportion of smokers at DPMC is similar to that in the general population [Tsai et al., 1992; Centers for Disease Control, 1989], smoking frequency and intensity could be lower among DPMC employees since there have always been stringent restrictions on cigarette smoking in the workplace. All these factors could contribute to the lower overall mortality seen.

The reduced mortality due to nonmalignant diseases, particularly for heart disease, is about the same as that due to all causes combined. The SMR for total cancer is higher than that for all causes. Unlike other diseases, cancer as a

TABLE VI. Observed Numbers of Deaths (OBS) and Standardized Mortality Ratios (SMR)[a] by Cause and Work Area, 1948–89, For Deer Park Male Study Population Hired After 1945

	Refinery (n = 3,795) 94178.4 person-years			Chemical plant (n = 3,690) 91800.6 person-years			Total (n = 7,485) 185981.2 person-years		
Cause of death (8th ICD revision)	OBS	SMR	95% CI[b]	OBS	SMR	95% CI	OBS	SMR	95% CI
All causes of death (001–999.8)	498	72.7	66–79	370	59.3	53–66	868	66.3	62–71
All malignant neoplasms (140–209)	122	77.0	64–92	116	80.4	66–96	238	78.6	69–89
Buccal cavity and pharynx (140–149)	3	59.4	12–173	5	112.9	37–263	8	84.4	36–166
Digestive organs and peritoneum (150–159)	24	66.9	42–99	21	66.0	41–101	45	66.5	48–89
Esophagus (150)	4	88.9	24–228	1	27.4	1–153	5	61.4	20–143
Stomach (151)	4	79.5	22–203	2	47.2	6–170	6	64.7	24–141
Large Intestine (153)	9	77.1	35–146	9	83.6	38–159	18	80.2	47–127
Rectum (154)	3	119.6	25–349	1	43.1	1–240	4	82.9	23–212
Biliary passages and liver primary (155,156)	1	26.6	1–148	0	—	—	1	14.2	.4–79
Pancreas (157)	2	27.3	3–99	7	105.8	42–218	9	64.6	29–123
Respiratory system (160–163)	50	74.3	55–98	48	78.5	58–104	98	76.3	62–93
Bronchus, trachea, lung (162)	47	72.7	53–97	47	80.0	59–106	94	76.2	61–93
Prostate (185)	8	113.2	49–223	4	64.6	18–165	12	90.5	47–158
Kidney (189.0,189.1,189.2)	5	130.5	42–305	4	112.1	31–287	9	121.7	56–231
Bladder and other urinary organs (188,189.9)	1	45.8	1–255	1	51.5	1–287	2	48.5	6–175
Malignant melanoma of skin (172.0–172.4,172.6–172.9)	1	30.6	1–170	4	120.5	33–308	5	75.9	25–177
Central nervous system (191,192)	5	95.6	31–223	5	98.3	32–229	10	96.9	46–178
All lymphatic and hematopoietic tissue (200–209)	11	72.6	36–130	12	83.9	43–146	23	78.0	49–117
Lymphosarcoma and reticulosarcoma (200)	2	87.2	10–315	1	46.0	1–256	3	67.2	14–196
Hodgkin's disease (201)	1	64.0	2–357	0	—	—	1	32.6	1–182
Leukemia and aleukemia (204–207)	6	103.5	38–225	7	128.7	52–265	13	115.7	62–198
All other lymphopoietic tissue (residual)	2	36.3	4–131	4	77.0	21–197	6	56.1	21–122
Diabetes mellitus (250)	6	81.1	30–176	1	15.1	0.4–84	7	49.9	20–103
Cerebrovascular disease (430–438)	19	66.8	40–104	19	79.2	48–124	38	72.5	51–99
All heart disease (390–8,400.1,400.9, 402,404,410–4,420–9)	169	73.3	63–85	117	56.2	46–67	286	65.2	58–73
Nonmalignant respiratory disease (460–519)	22	67.1	42–101	17	58.2	34–93	39	62.9	45-86
Cirrhosis of liver (571)	9	37.4	17–71	7	31.3	13–64	16	34.5	20–56
Accidents (800–949)	53	80.1	60–105	37	58.7	41–81	90	69.7	56–86
Suicides (950–959)	17	66.2	39–106	9	34.9	16–66	26	50.5	33–74
Homicides and other external causes (residual)	15	42.2	24–70	8	24.9	11–49	23	34.0	21–51
Unknown causes of death (999.9)	15	—	—	8	—	—	23	—	—

[a]Expected numbers of death based on Harris County population, ICD Revision in effect at time of death.
[b]95% confidence interval.

whole has a relatively long latency and lacks a well-defined etiology. Applicants for employment were unlikely to be screened out for potential cancer risk factors during preplacement evaluation. In addition, because employees usually participate in health insurance programs provided by the company, they may be more likely to have a cancer diagnosed and noted as a cause of death on the death certificate than a member of the general population (many of whom are uninsured or underinsured). Thus, the healthy worker effect may have little or no impact on the SMRs for malignant neoplasms.

The unusual features of the petroleum workforce during World War II related to the drafting of most healthy young men into the military and the subsequent staffing of civilian jobs by women, less fit men, and others who under usual circumstances would not have been in the workforce have been reported by others [Wen et al., 1986]. Because of this and the fact that post-1945 plant operations are deemed more representative of the current operations, the mortality experience of those hired after 1945 was examined. There was no statistically significant increased risk due to any cause of death in this group.

The previous DPMC study [Marsh et al., 1991] reported increasing SMRs for cancers of the central nervous system, biliary passages and liver, and leukemia with increasing duration of employment in the male refinery population. This update has found that SMRs for cancer of the central nervous system remained stable for the three duration of employment groups, with SMRs ranging from 100 to 106. The SMR for cancer of the biliary passages and liver was reduced substantially (SMR = 146; 30–427) among employees who had 30 or more years of employment in the refinery operation as compared to the corresponding group in the previous study (SMR = 312). For leukemia in the refinery population, the upward trend in SMRs was no longer present in this update study, although SMRs were slightly higher in the longer duration of employment groups. In addition, during the update period 1984–1989, the SMRs for cancer of the biliary passages and liver and leukemia for employees who worked 30 or more years were 0 and 74, respectively.

Consistent with the previous study, mortality for cancers of the lymphopoietic tissue among refinery employees was statistically increased with increasing duration of employment, particularly for lymphoreticulosarcoma. An examination of the nine refinery employees' work histories revealed no predominant pattern of job type, work area, or process operation. The longest job for the nine lymphoreticulosarcoma cases included cargo inspector (21 years), lube A operator/foreman (35 years), valve repairer (15 years), staff assignment (16 years), dispatching docks (3.5 years), control laboratory testing (27 years), laborer (18 years), laborer (20 years), and boilermaker (13 years). The average age at death for the lymphosarcoma cases was 65 years; the average duration of employment was 27.2 years (range 6–33 years); 7 of the cases were hired before 1946. Similar findings were also noted among chemical plant employees in this study. The magnitudes of increase, however, have been greatly reduced particularly among longer duration of employment groups. For example, the all lymphopoietic tissue cancer SMR for 30 or more years of employment in the chemical plant was 434 (with 2 observed deaths) in the previous study compared to 203 (with 4 observed deaths) in this update; the contribution of the 6-year follow-up from 1984 to 1989 yields an SMR of only 132 (16–478).

Increased SMRs for cancer of the lymphopoietic tissue have been reported in other studies of petroleum workers [Delzell et al., 1988; Wong and Raabe, 1989; Wongsrichanalai et al., 1989]. Several studies with length of employment analysis indicated an increased mortality from this broad category of cancer with increasing length of service. This pattern was also noted for lymphoreticulosarcoma, leukemia, and cancer of all other lymphatic tissue. Further analyses in this update by hire date showed that the increases in lymphoreticulosarcoma and cancer of all other lymphatic tissue were confined to employees hired before 1946. Leukemia was not increased among refinery employees but was elevated, although not statistically significantly so, among chemical plant employees. The results of this update may suggest that the increases of these cancers could be related to factors in the early years of DPMC operations. It should be noted that 3 (2 refinery and 1 chemical) of the 21 leukemia decedents were hired in 1946, and 2 additional leukemia deaths among chemical plant employees were hired in 1948. If the hire date analyses were based on a different date such as January 1, 1949 as suggested by others [Wong et al., 1986; Dagg et al., 1992], the increased leukemia mortality among chemical plant employees would disappear.

A review of the detailed individual work histories did not reveal any common work areas or job assignments for leukemia cases within chemical plant operations. Leukemia cell types included one acute lymphocytic leukemia, one chronic lymphocytic leukemia, three acute myelocytic leukemias, one erythroleukemia, and one unspecified acute leukemia. The average duration of employment was 23 years (range 0.5–32 years), and the average age at death was 62 years (range 54–77). Latencies for individual cases ranged from 19 to 41 years, with an average of 32 years.

It is noteworthy that for cancers known to have a rather long survival, such as Hodgkin's disease or certain lymphomas, mortality data could underestimate actual incidence in both the study and comparison populations. In addition, there will be fewer numbers of observed (and expected) cases for cancers with long survival time in a mortality study and hence reduced statistical power to detect a difference of these cancers. However, for lymphohematopoietic cancers with short survival, such as acute granulocytic leukemia, mortality results would approximate cancer incidence.

Increased mortality from cancer of the respiratory system among petroleum workers has been reported in the literature [Blot et al., 1977; Hanis et al., 1979, 1985b; Gottlieb et al., 1979; Gottlieb, 1980; Buffler et al., 1984]. The lack of any elevation in respiratory system cancer in this study is made credible by a significant deficit in nonmalignant respiratory diseases. These findings may be due, in part, to a lower smoking frequency among DPMC employees. This study also failed to show an increased mortality risk from cancers of the central nervous system, stomach, or prostate, as had been reported in other petroleum industry studies [Delzell et al., 1988; Wong and Raabe, 1989].

A 30% deficit in malignant melanoma of the skin was noted among DPMC refinery employees, whereas an increased mortality from this cancer has been reported in other studies of petroleum workers [Schottenfeld et al., 1981; Rushton and Alderson, 1981a; Nelson et al., 1987; Delzell et al., 1988; Wong and Raabe, 1989]. A statistically nonsignificant increase in malignant melanoma of the skin

TABLE VII. Detailed Job Histories of Deer Park White Male Employee Mesothelioma Cases

Case no.	Age at hire	Year of death	Age at death	Job title	Years worked[a]
1	37	1967	61	General helper	9/42–5/43
				Insulator	5/43–9/64
2	22	1979	49	General helper	7/52–9/52
				Cracking	9/52–1/53
				Insulator	1/53–8/62
3	29	1976	61	General helper	1/45–3/45
				Welder	3/45–6/76
4	27	1980	63	General helper	3/45–3/45
				Automotive	3/45–4/45
				General helper	4/45–4/45
				Automotive	4/45–4/45
				General helper	4/45–4/45
				Boilermaker	4/45–9/47
				Instrument man	9/47–8/62
5	29	1984	65	General helper	8/47–9/47
				Boilermaker	9/47–3/57
6	18	1986	68	Laborer	8/36–10/36
				Laboratory tester	10/36–5/37
				Cracking	5/37–7/46
				Catalytic cracking	7/46–1/56
				Aromatics	1/56–3/62
				Catalytic cracking	3/62–12/64
				Staff assignment	12/64–5/67
				Staff assignment	4/78–5/82
7	23	1986	79	Machinist	9/29–1/47
				Automotive	1/47–12/63

[a]Dates do not account for absences due to strikes, military leave, and other reasons.

was seen among DPMC chemical plant employees. A review of job histories for these melanoma cases did not suggest a common work-related component. The average time worked was 10 years (range 5–24), and 58 years was the average age at death. All decedents were hired prior to 1957.

A concern of expanding the cohort to include the employees hired after 1972 in this update study is that the results could have been diluted. To assess this possible effect, we have also examined the original Marsh cohort [1991] with a longer follow-up through 1989. The cause specific mortality patterns for cancer was virtually the same as those presented earlier. The overall mortality for the original cohort was approximately 10% higher than the expanded cohort (Table III) for both refinery (SMR = 88, 95% CI = 83–93) and chemical (SMR = 68, 95% CI = 62–74) groups; this is primarily due to the relative contribution from heart disease. The mortality rates for all cancer, however, were the same (SMR = 86, 95% CI = 76–96 for refinery and SMR = 79, 95% CI = 67–93 for chemical) as those exhibited in Table III. Analysis by duration of employment of this cohort revealed no new findings, hence does not change our conclusions expressed herein.

One finding not previously noted for this complex is the increased mortality from mesothelioma, a cancer linked to asbestos exposure. Mesothelioma has a latency of 30–40 years from first exposure [Fraumeni and Blot, 1982; Lanphear and Buncher, 1992], so the increased mortality reflects asbestos exposure well before all current, stringent controls were instituted. A number of recent studies have reported an increase in mesothelioma mortality among petroleum workers [Kaplan, 1986; Schnatter et al., 1992; Gennaro et al., 1994; Honda et al., 1995].

Table VII displays selected characteristics of the seven mesothelioma deaths. Five of the seven mesothelioma decedents were hired before 1946, and three had less than 20 years of employment duration. An examination of their work histories revealed that six of the seven cases had been employed in maintenance positions, and one in production. The longest jobs for the seven cases included cracking and catalytic cracking operator/foreman (21 years), insulator (20 years), insulator (10 years), welder (30 years), instrument man (15 years), boilermaker (9 years), and automotive foreman (19 years). Most of these job assignments are likely to have had some levels of occupational exposure to asbestos, a recognized cause of mesothelioma. The average age of death was 64 years (range 49–79 years). The average duration of employment was 22 years (range 9–34 years), and 31 years was the average latency for the group (range 19–38 years). The two cases hired after 1945 had 9 and 10 years duration of employment, with an average latency of 32 years. The mesothelioma SMR for this subgroup hired after 1945 was 106 with 2 deaths observed and 1.88 expected (13–384), compared to 382 with 5 observed and 1.31 expected (124–889) for those hired before 1946.

CONCLUSIONS

This mortality update represents more than 40 years of follow-up of a large population of refinery and petrochemical plant employees. Similar to most other cohort studies of refinery and petrochemical workers, the overall mortality of DPMC employees was quite favorable compared to residents in the local population. For causes of death in which a possible suspicion of work-relatedness was raised in the original study, no supportive evidence for such findings was found in this update. In fact, in this extended analysis, the apparent associations previously reported are now lower. The elevations that have been seen (i.e., cancers of all lymphatic and hematopoietic tissue) are primarily confined to employees who started work at the complex before 1946. In contrast, deaths from this cancer for employees hired after 1945 were more than 20% lower than the comparison population. In addition, the increased cancer mortality risks suggested in the literature for refinery and petrochemical workers (i.e., brain, stomach, lung, kidney, and prostate) were not found in this study. Additional subgroup analyses of this population are planned to examine more closely the mortality patterns of employees in job groups with potential for common specific exposures.

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