A Retrospective Mortality Study of Workers in Three Major U.S. Refineries and Chemical Plants

Part 1: Comparisons with U.S. Population

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A dynamic retrospective cohort study was performed to examine the mortality experience of 27,698 workers at Exxon's refineries and chemical plants in Baton Rouge, la.; Baytown, Tex.; and Bayway/Bayonne, N.J. Included were 15,437 regular employees who worked at least one month during the period Jan. 1, 7970, through Dec. 31, 1977, and 6,267 retirees who were alive as of Jan. 7, 7970. There were 137,702 person-years of observation. Mortality in this total study population was generally lower than that of the U.S. population. Study follow-up was complete for 98.7% of the study population. The standardized mortality ratio for the 3,798 deaths was 91, while that for deaths from all cancers (N=666) was 94. Certain slightly elevated disease-specific mortality ratios, although not statistically significant, could be of biological importance and merit further review.

Cohorts of workers from three Exxon refineries and chemical plants in the United States were selected for mortality studies for the period 1970 through 1977. The study included employees at three plant sites, located in Louisiana, Texas, and New Jersey.

The primary purpose was to compare the observed mortality in each plant population with that of the U.S. population of similar age, sex, and race. Results of the study of the Louisiana plant cohort were published in 1982.[1] The three worker populations have been combined into a single cohort to address the following objectives:

1. To compare the mortality experience of the total study population with that of the U.S. population.
2. To develop an internal comparison group for comparing subgroups within the cohort.
3. To compare mortality rates (directly adjusted for age, race, sex, and calendar year) among the three plant cohorts using the internal comparison group as the standard.
4. To compare mortality rates in the total study population by race, occupational categories, and smoking history.

This report presents the results of the mortality comparison of this total study cohort and the U.S. population (objective one). Results relating to the remaining objectives will be dealt with in another report.

Materials and Methods

Study Design and Cohort Definition — A retrospective cohort study design was used to examine the mortality experience of workers at three Exxon U.S. refineries and chemical plants. This population was dynamic, in that employees entered the 1970 through 1977 observation period at various times and remained for varying periods. Mortality due to all causes and to selected specific causes was explored.

The total study population (N=21,698) included 15,437 full-time regular employees with at least one month of service at any of the three U.S. plant sites (Baton Rouge, La.; Baytown, Tex.; Bayway/Bayonne, N.J.) during the eight-year period Jan. 1, 1970, through Dec. 31, 1977. All 6,261 retirees who were alive as of Jan. 1, 1970, were also included in the population at risk. Employees who worked at more than one plant site were given credit for the years spent at each plant in the mortality analyses but were only counted once in each of the total population description

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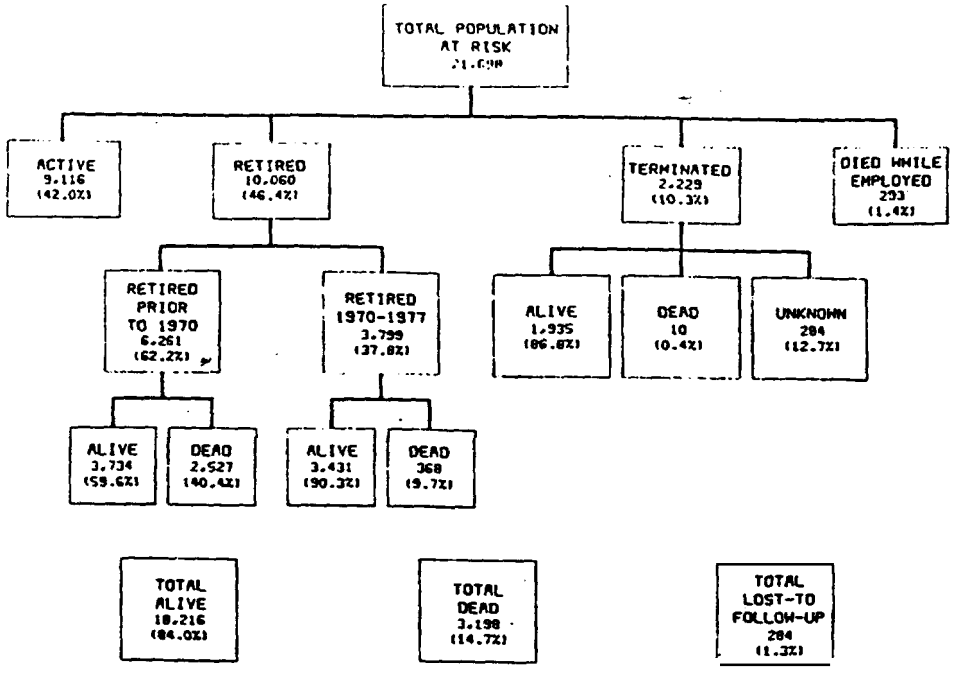

Description of study population.

tables. There were 60 of these "multiple date of entry" employees.

Data Collection and Handling — Extracts from company personnel and medical records provided Social Security number, company identification number, name, date of birth, sex, race, date of employment, date of termination, and status of last observation for each member of the study population. Date of death and underlying cause of death were extracted from death certificates. The underlying cause of death was coded by a trained nosologist according to the eighth revision of the *International Classification of Diseases (ICDA).*[2] In 25 instances where death certificates were unavailable, information from death notices or company medical records was used.

The U.S. cause-specific mortality rates by age. sex, race, and calendar year were used for comparison with the mortality experience of the total study population.

Analytical Methods — Standardized mortality ratios (SMRs) were used for comparing the mortality experience of the total study population with that of the U.S. population.[3] The following method was used to calculate the SMRs as percents:.

$$SMR = \frac{O}{E} \times 100$$

where O indicates the observed number of deaths in the study population for a specific cause of death: and E, the expected number of deaths in the study population, calculated by multiplying the age-, sex-, race-, calendar year–, and cause-specific mortality rates of the standard U.S. population by the corresponding number of person-years at risk in the study population. Person-years at risk equals the sum of the total years of observation for members of the study population as they pass through each five-year age group, each five-year calendar period, and each plant. This is sometimes referred to as a modified life-table approach..

SMRs calculated for different study populations are not

Table 1 — Distribution of Total Study Population by Age, Race, and Sex at Entry Into Cohort

	White*				Black					
	Male		Female		Male		Female		Total	
Age, yr	NO.	%	NO.	%	No.	%	No.	%	No.	%
<20	237	1.3	74	6.6	60	3.0	19	12.7	390	1.8
20-24	2.657	14.4	333	29.7	565	27.9	65	43.3	3.620	16.7
25-29	1,971	10.7	130	11.6	333	16.4	40	26.7	2,474	11.4
30-34	699	3.8	79	7.1	98	4.8	13	8.7	889	41
35-39	388	21	51	4.6	31	1.5	5	3.3	475	2.2
40-44	845	4.6	83	7.4	28	1.4	3	2.0	959	4.4
45-49	1,643	8.9	98	8.8	66	3.3	1	0.7	1.808	8.3
50-54	1,985	10.8	72	6.4	139	6.9	0	0.0	2.196	10.1
55-59	2.097	11.4	63	5.6	190	9.4	0	0.0	2.350	10.8
60-64	1,889	10.3	60	5.4	176	8.7	2	1.3	2,127	9.8
65-69	1.589	8.6	40	3.6	136	6.7	0	0.0	1,765	8.1
70-74	1,164	6.3	17	1.5	96	4.7	1	0.7	1,278	5.9
75-79	783	4.3	12	1.1	61	3.0	1	0.7	857	3.9
80-84	341	1.9	6	0.5	30	1.5	0	0.0	377	1.7
85+	114	0.6	2	0.2	17	0.8	0	0.0	133	0.6
Total	18,402	100.0	1,120	100.1	2,026	100.0	150	100.1	21,698	99.8
% of Total	85		5		9		1		100.0	

*Includes minorities other than black

Table 2 — Distribution of Total Study Population by Year of Employment

Year of Employment	Employee* No.	Employee* %	Deaths† No.	Deaths† %
1900-1909	190	0.9	151	4.7
1910-1919	1,295	6.0	727	22.7
1920-1929	2.908	13.4	1.046	32.7
1930-1939	2.307	10.6	404	12.6
1940-1949	6.177	28.5	796	24.9
1950-1959	824	3.8	25	0.8
1960-1969	3.104	14.3	32	1.0
1970-1977	4,893	22.6	17	0.5
Total	21.698	100.1	3,198	99.9

* Employees hired during specific employment period

† Deaths of employees hired during specific employment period

directly comparable with one another since the computation involves an indirect adjustment procedure.[5,6] A result was considered for further discussion if (1) its SMR was based on five or more deaths and exceeded 100 and/or (2) its SMR was statistically significant at $p<.05$.

Results

Description of the Study Population — As shown in the Figure, of the total population of 21,698 employees, 42% were alive and still employed at the end of the observation period, 46% had retired (of these, 29% died during the study period), 10% had terminated employment before retirement, and 1% had died while still employed. Ninety-one percent of the total deaths (N=3,198) occurred among retirees. Follow-up for vital status was successful for all but 284 (1%) of the study subjects. The 21,698 employees contributed 137,702 person-years for the eight-year observation period.

Table 3 — Distribution at Deaths by Year, 1970 Through 1977

Year of Death	No.	%
1970	401	12.5
1971	396	12.4
1972	425	13.3
1973	442	13.8
1974	391	12.2
1975	382	11.9
1976	370	11.6
1977	391	12.2
Total	3.198	99.9

At date of entry into the cohort, white males accounted for 85% of the total population, white females for 5%, black males for 9%, and black females for 1% (Table 1). There was a bimodal age distribution among white males, with peaks at ages 20 through 24 and 55 through 59. In the younger age groups there were higher proportions of females and black males than of white males.

Approximately 59% of the total population was employed prior to 1950; this group contributed 98% of the deaths. Twenty-three percent of the employees began employment during the eight-year observation period (Table 2).

Deaths were evenly distributed throughout the eight years (Table 3). Death certificates were available for all but 0.8% (N=25) of the study population deaths (N=3,198).

Sixty-one percent of all deaths were due to diseases of

Table 4 — Distribution of Deaths by Major Cause, 1970 Through 1977

Major Cause of Death*	NO.	%	U.S. rot
Infective/parasitic diseases (000-136)	20	0.6	0.6
All neoplasms (140-239)	675	21.1	19.3
Endocrine/nutritional/metabolic diseases (240-279)	59	1.8	2.3
Diseases of blood/blood-forming organs (280-289)	9	0.3	0.3
Mental disorders (290-315)	6	0.2	0.5
Diseases of nervous system/sense organs (320-389)	15	0.5	0.9
Diseases of circulatory system (390-458)	1,946	60.9	52.2
Diseases of respiratory system (460-519)	164	5.1	5.9
Diseases of digestive system (520-577)	93	2.9	3.7
'Diseases of genitourinary system (580-629)	51	1.6	1.3
Diseases of skin/subcutaneous tissue (680-709)	1	—	0.1
Oiseases of musculoskeletal system connective tissue (710-738)	6	0.2	0.3
Symptoms/senility/ill-defined conditions (780-796)	42	1.3	1.7
All external causes (E800-E999)	111	3.5	8.3
Total	3,198	100.0	97.6

Table 5 — Distribution of Oeaths Due to Malignant Neoplasms by Major Site. 1970 Through 1977

Cancer Oeath Site'	No.	%	U.S. %†
Buccal cavitylpharynx (140-149)	14	2.1	2.2
All digestive organs (150-159)	196	29.4	27.2
All respiratory system (160-163)	217	32.6	23.7
Bone/connective tissue/skin/breast (170-174)	17	2.6	11.2
All genitourinary organs (180-189)	100	15.0	16.3
Other and unspecified (190-199)	67	10.1	9.9
All lymphopoietic (200-209)	55	8.3	9.5
Total	666	100.1	100.0

'ICDA. eighth revision codes shown in parentheses

† Percent based on proportion of cancer category in relation to number of total cancer deaths'

the circulatory system and 21% were due to malignant neoplasms (Table 4). Deaths of unknown cause (1% of total deaths) were included in the symptoms/senility/ill-defined category. Table 5 shows the distribution of site-specific cancer deaths. One third of the cancer deaths were due to respiratory system neoplasms, while 29% were due to cancers of the digestive system. In the 1975 U.S. population, 52% of all deaths were due to diseases of the circulatory system and 19% were due to malignant neoplasms; of these malignant neoplasms, 24% were in the respiratory system and 27% were cancers of the digestive system.'

Comparison of the Mortality Experience of the Total Study Population with That of the US. Population — The numbers of deaths due to all causes (SMR = 91), to mental disorders (SMR = 40), to diseases of the respiratory system (SMR = 64), to diseases of the digestive system (SMR = 71), and to all external causes (SMR = 56) were significantly lower ($p < .05$) than expected. Deaths due to benign/unspecified neoplasms (SMR = 1321 and to diseases of blood/blood-forming organs (SMR = 120) were greater than expected, but the increases were not statistically significant (Table 6)

The number of observed deaths for all malignant neoplasms was less than expected (SMR = 94), but the difference was not statistically significant. Other cancer sites of interest for which numbers of observed deaths were less than expected included lung (SMR = 95), skin (SMR = 99), genitourinary organs (SMR = 83), leukemia (SMR = 77), and all lymphopoietic cancers (SMR = 89). SMRs for six sites were greater than 100, based on five or more deaths, but none were statistically significant. Rates were elevated for cancers of the liver/gallbladder/bile ducts (SMR = 133),

Table 6 — Standardized Mortality Ratios (SMRs) for Selected. Major Causes of Oeath, 1970 Through 1977†

Cause of Death‡	Observed/ Expected§	SMR	CI*
All causes of death (000-999)	3,198/3,515.2	91	88-94
Infective and parasitic diseases (000-136)	20/24.0	83	51-128
Malignant neoplasms (140-209)	666/705.0	94	87-102
Benign/unspecified neoplasms (210-239)	9/6.8	132	61-252
Endocrine/nutritional/metabolic diseases (240-279)	59163.9	92	70-119
Diseases of blood/blood-forming organs (280-289)	9/7.5	120	54-226
Mental disorders (290-315)	61149	40	15-88
Diseases of nervous system/sense organs (320/389)	15/24.0	63	35-103
Diseases of circulatory system (390-458)	1,946/1,980.8	98	94-103
Oiseases of respiratory system (460-519)	164/254.4	64	55-75
Diseases of digestive system (520-577)	93fl30.5	71	58-87
Oiseases of genitourinary system (580-629)	51/50.5	101	75-133
Diseases of musculoskeletal system/connective Tissue (710-738)	6/5.8	103	38-115
Symptoms/senility/ill-defined conditions (780-796)	42/44.2	95	67-126
All external causes (E800-E999)	1111197.2	56	46-68

• SMRs were not included when the observed number of deaths was less than five (diseases of skin/subcutaneous tissue [680-709] had only one death)

† total: person-years = 137,702.5; number of employees = 21,698: number of deaths = 3,198

‡ *ICDA.* eighth revision codes shown in parentheses

§ Expected number of deaths based on age-, sex-, race-. and cause-specific U.S. population rates calculated for each five-year calendar period.

‖ SMR is statistically significant at $p < .05$ if confidence interval (CI) does not include 100

Table 7— Standardized Mortality Ratios (SMRs) for Deaths Due to Selected* Malignant Neoplasms, 1970 Through 1977

Cancer Death Site†	Observed/Expected‡	SMR	CI§
All malignant neoplasms (140-2091	666/705.0	94	87-102
Buccal cavity/Pharnyx (140-149	14/19.8	71	39-119
All digestive organs (150-159)	196/195.3	100	87-115
Esophagus (150)	15/17.2	87	49-144
Stomach (151)	33/34.3	96	66-135
Large intestine (153)	67/68.1	98	76-125
Rectum (154)	19121.1	90	54-140
Liver/gallbladder/bile ducts (155-156)	15/11.3	133	74-219
Pancreas (157)	42/39.2	107	77-145
All respiratory system (160-163)	217/231.6	94	82-107
Larynx (161)	719.9	71	29-147
Lung (162)	209R19.8	95	83-109
Bone/connective tissue/skin/breast (170-174)	17114.3	119	69-190
Skin (172-173)	9/9.1	99	45-188
All genitourinary organs (180-189)	100/120.6	83	67-101
Prostate (185)	56173.3	76	58-100
Bladder (188)	19125.3	75	45-117
Kidney (189)	22/15.4	143	90-217
Brain/CNS (191-192)	1511 3.0	115	65-191
All lymphopoietic (200-209)	55/61.8	89	67-116
Lymphosarcoma/reticulosarcoma (200)	13/11.4	114	61-196
Leukemia (204-207)	20R5.9	77	47-11o
Other lymphatic tissue (202,203,208)	15/18.6	81	45-133

* SMRs were not included when the observed number of deaths was less than five

† *ICDA*, eighth revision codes shown in parentheses

‡ Expected number of deaths based on age-, sex-, race-, and cause-specific U.S. population rates calculated for each five-year calendar period

§ SMR is statistically significant at $p<.05$ if confidence interval (CI) does not include 100

pancreas (SMR=107), bone/connective tissue/skin/breast (SMR=119), kidney (SMR=143), and brain/CNS (SMR=115) and for lymphosarcomas/reticulosarcomas (SMR=114) (Table 7).

Among employees who were actively employed at some time during the study period, the observed numbers of deaths for several causes were significantly lower than expected. The SMR for all causes of death combined was 62 and the SMR for all malignant neoplasms was 76. However, four of the six cancer sites for which slight excesses of deaths were observed in the total study population showed similarly elwated SMRs in this group. These were cancers of the liver/gallbladder/bile ducts (SMR=139), kidney (SMR=148), and brain/CNS (SMR=135) and lymphosarcomaslreticulosarcomas (SMR=130) (Table 8).

To examine the possible effect of latency, employees who had had 15 or more years of employment (hired prior to 1956) at these plants were examined separately. The results of the comparison of the mortality experience of this group with that of the U.S. population were similar to those observed in the comparison of the total study population mortality with that of the U.S. population, except that the SMR of 90 for all malignant neoplasms was significantly lower than expected (Table 9).

The mortality ratios for white males were very similar to those of the total study population. Overall mortality ratios for black males were below 100 (all causes, SMR=97; all malignant neoplasms, SMR=92). There were a few causes of death for which SMRs were greater than 100, although none of these was statistically significant. They included diseases of the circulatory system (SMR=116), diseases of the genitourinary system (SMR=120), and cancers of the digestive organs (SMR=131) (Table 10).

Comparison of the Mortality Experience of cohorts at Three Separate Sites With That of the U.S. Population — Mortality among each of the three plant site populations was compared with that of the U.S. population. Tables 11 and 12 provide extracts from these results. SMRs for major causes of death were included in Table 11 if the SMR was statistically significant ($p<.05$) for any one of the three plant populations. For many causes of death, the numbers of observed deaths were lower than expected and many of the low SMRs were statistically significant. For the Bayway/Bayonne population, SMRs were high in two categories — malignant neoplasms and endocrine/nutritional/metabolic diseases, (both of which were statistically significant). In general, the mortality from malignant neoplasms in Baton Rouge and Baytown compared favorably with that in the U.S. population. SMRs for cancers of the brain/CNS and the kidney were 100 or above in all locations. None of these differences were statistically significant. In the Bayway/Bayonne population, elevations of the SMRs for

Table 8 — Standardized Mortality Ratios (SMRs) for Selected* Causes of Death In Active Employees† 1970 through 1977‡

Cause of Death§	Observed/Expected‖	SMR
All causes of death (000-999)	670/1074.1	62¶
All malignant neoplasms (140-209)	183/240.8	76¶
All digestive organs (150-159)	48/60.8	79
Liver/gallbladder/bile ducts (155-156)	5/3.6	139
Pancreas (157)	11/13.1	84
All respiratory system (160-163)	65/93.5	70F
Lung (162)	64/88.7	729
All genitourinary organs (180-189)	23/25.5	90
Prostate (185)	8/10.5	76
Kidney (189)	9/6.1	148
Brain CNS (191-192)	10/7.4	135
All lymphopoietic (200-209)	19/21.8	87
Lymphosarcoma/reticulosarcoma (200)	6/4.6	130
Leukemia (204-207)	6/8.0	75
Diseases of Circulatory system (390-458)	340/510.1	67¶
Diseases of. respiratory system (460-519)	16/59.3	27¶
Oiseases of digestive system (520-577)	32/58.3	55¶
Oiseases of genitourinary system (580-629)	8/10.6	75

* SMRs were not included when the observed number of deaths was less than five
† Employees actively employed between Jan. 1, 1970, and Dec. 31, 1977
‡ Total: person-years = 98.149; number of employees = 15,437; number of deaths = 670
§ *ICDA.* eighth revision codes shown in parentheses
‖ Expected number of deaths based on age-, sex-, race-, and cause-specific U.S. population rates calculated for each five-year calendar period
¶ SMR is statistically significant at $p < .05$

all malignant neoplasms and all digestive organ cancers were statistically significant; excesses of respiratory system cancers were of borderline significance. Other cancers with greater than expected numbers of deaths (not statistically significant) in the Bayway/Bayonne population included those of the buccal cavity/pharynx, brain/CNS, and other/secondary/unspecified sites.

Discussion

Employees with less than one month of employment and nonregular employees were excluded from the study population. Because of their short duration of employment, it is very unlikely that deaths among these employees would be related to their employment in these petroleum and petrochemical plants.

Study follow-up was 98.7% complete, and it is highly unlikely that the absence of information on these employees could have biased mortality results.' The 3,198 deaths observed during the study period were distributed evenly throughout eight years, and official death certificates were obtained for 99% of all deaths. Thus, it is very unlikely that more complete death verification would change the results. Data on variables of interest did not represent a problem in this study because the amount of missing data was low; work histories were available for 97% of all employees, and date of employment was available for 99.9% of all employees, and date of birth, race, and sex were known for all employees.

In general, this population compared favorably with the U.S. population for major causes of death. Some slightly elevated SMRs could be of biological importance even though they were not statistically significant.

Employed populations have been estimated to have an overall mortality risk lower (on the order of 10% to 40% less) than that of the general population because of the so-called "healthy worker effect."[7] The mortality ratio for all causes of death in this study was 91. In this investigation, the inclusion of a large group of retirees diminishes the impact of the healthy worker effect usually observed in industrial cohort studies. Most occupational epidemiology studies have not included this group. The greatest proportion of this study population was employed before the beginning date of observation. When the workers who were actively employed during the study period were examined separately, mortality among the active employees was much lower than that of the U.S. population. In fact, the SMR for all causes of death after exclusion of the pre-1970 retirees was 62 as compared with an SMR of 91 when these retirees were included. Four of the six cancer sites for which greater than expected numbers of deaths were observed in the total population analysis were also observed to have SMRs greater than 100 in the actively employed group. These findings support the contention that any healthy worker effect probably occurs in younger populations with fewer years of employment and may not act on site-specific cancer mortality rates.'

The possibility that the younger, short-term workers could have diluted any occupational latency effect in the total study population was examined by analyzing the popula-

Table 9 — Standardized Mortality Ratios (SMRs) for Selected* Causes of Death in Employees Hired Before 1956, 1970 Through 1977†

Cancer Death Site‡	Hired Prior to 1956 Observed/Expected§	SMR
All causes of death (000-999)	3,147/3,403.1	92‖
All malignant neoplasms (140-209)	613/684.2	90‖
Buccal cavity/pharynx (140-149)	14/19.3	73
All digestive organs (150-159)	181/190.5	95
Esophagus (150)	13/16.8	77
Stomach (151)	30/33.5	90
Large intestine (153)	63/66.5	95
Rectum (154)	18/20.6	87
Liver/gallbladder/bile ducts (155-156)	14/11.0	127
Pancreas (157)	38/38.3	99
All respiratory system (160-163)	201/226.0	89
Lung (162)	193/214.5	90
All genitourinary organs (180-189)	95/117.5	81
Prostate (185)	51/72.1	71‖
Bladder (188)	19/24.9	76
Kidney (189)	22/15.0	147
Brain/CNS (191-192)	14/12.0	117
All lymphopoietic (200-209)	44/58.5	75
Lymphosarcoma/reticulosarcoma (200)	9/10.8	83
Leukemia (204-207)	17/24.5	69
Diseases of circulatory system (390-458)	1,940/11,958.7	99
Diseases of respiratory system (460-519)	162/250.8	65‖
Diseases of digestive system (520-577)	91/125.0	73‖
Diseases of genitourinary system (580-629)	51/49.6	103

* SMRs were not included when the observed number of deaths was less than five
† Total: person-years = 95,436.1; number of employees = 13,428; number of deaths = 613
‡ ICDA, eighth revision codes shown in parentheses
§ Expected number of deaths based on age-, sex-, race-, and cause-specific U.S. population rates calculated for each five-year calendar period
‖ SMR is statistically significant at $p<.05$

tion of all workers hired before 1956. The results indicated no dilution effect. The distribution of deaths and the short observation period precluded detailed analyses by latency. This problem can be solved in the future by increasing the observation period retrospectively and/or prospectively. An extended observation period would also result in an increased number of observed deaths, which would improve the statistical power for examining more detailed stratified analyses.

In comparison with the U.S. black population, black employees were observed to have an excess number of digestive cancers, mainly those of the stomach and pancreas, but these were based on very small numbers. These diseases have been associated in other studies with socioeconomic status, diet, and exposure to asbestos.. There was no way to examine these factors in this study because the data were unavailable. However, because this subgroup was very small, further analyses and speculations would be unreliable.

Comparisons of the mortality experience of employees at individual plant sites with that of the U.S. population indicated some areas for further study. The excess of pancreatic cancer deaths observed in the Baton Rouge plant population is being reviewed in a case-control study, presently under way at Louisiana State University, whose purpose is to examine the high incidence of pancreatic cancers in Louisiana. The excess of brain/CNS cancers observed in the Baytown population was not statistically significant and not apparently associated with potential for exposures on specific jobs. Further insight may be gained from a Gulf Coast case-control study to be conducted by investigators at the University of Texas and Louisiana State University.'

In light of the publicity alluding to New Jersey as "cancer alley," digestive organ and respiratory site cancers were examined using New Jersey and local county rates as the standard (Table 13). The differences between the observed and expected numbers of deaths for digestive organ and respiratory site cancers diminished when these rates were applied, suggesting that regional factors were influencing mortality in this population. More detailed analyses using local and state rates as the standard for each of the three sites would provide more information relative to geographical differences.

Four other cohort mortality studies of petroleum and petrochemical workers whose results were published or reported in the 1974 through 1982 period showed similarly low SMRs for all causes of death and for all cancer deaths,[10-14] even though the observation periods and co-

Table 10 — Standardized Mortality Ratios (SMRs) for Selected* Causes of Death by Race, 1970 Through 1977

Cause of Death‡	White Males† Observed/Expected§	SMA	Black Males Observed/Expected§	SMR
All causes of death (000-999)	2,874/3,172.7	91‖	284/293.7	97
Malignant neoplasms (140-209)	603/634.1	95	54/58.7	92
All digestive organs (150-159)	171/174.5	98	23/17.6	131
Stomach (151)	26/29.5	88	7/4.4	159
Large intestine (153)	61/62.4	98	5/4.3	116
Pancreas (157)	35/35.4	99	6/3.3	182
All respiratory system (160-163)	201/212.5	95	14/17.6	80
Lung (162)	193/201.8	96	14/16.6	84
All genitourinary organs (180-189)	94/103.8	91	6/12.1	50
Prostate (185)	51/63.7	80	5/9.6	52
Endocrine/nutritional/metabolic diseases (240-279)	52/55.9	93	6/6.4	94
Diseases of circulatory system (390-458)	753/1,809.8	97	168/145.1	116
Diseases of respiratory system (460-519)	150/235.0	64‖	14/17.1	82
Diseases of digestive system (520-577)	83/117.7	71‖	7/10.7	65
Diseases of genitourinary system (580-629)	42/42.4	99	9/7.5	120
All external causes (E800-E999)	91/166.6	55‖	19/27.8	68
Total No. of person-years	120,053.0		11,550.9	
Total No. of employees	18,402		2,026	
Total No. of deaths	2,874		284	

* SMRs were not included when the observed number of deaths was less than five in either group
† Includes minorities other than black
‡ ICDA, eighth revision codes shown in parentheses
§ Expected number of deaths based on age-, sex-, race-, and cause-specific U.S. population rates calculated for each five-year calendar period
‖ SMR is statistically significant at $p<.05$.

Table 11 — Standardized Mortality Ratios (SMRs) for Selected* Major Causes of Death for the Three Plant Populations at Risk, 1970 Through 1977

Cause of Death	Baton Rouge Observed/Expected†	SMR	CI‡	Baytown Observed/Expected†	SMR	CI‡	Bayway/Bayonne Observed/Expected†	SMR	CI‡
All causes of death (000-999)	1,205/1,320.8	91	86-97	784/982.5	80	74-86	1,209/1,213.1	100	94-105
Malignant neoplasms (140-209)	249/272.0	92	81-104	158/209.9	75	64-88	259/223.3	116	102-131
Endocrine/nutritional/metabolic diseases (240-279)	18/24.6	73	43-116	9/17.7	51	23-97	32/21.6	148	101-209
Mental disorders (290-315)	11/6.2	176	88-315	2/4.7	42	5-152	3/4.0	75	15-220
Diseases of circulatory system (390-458)	729/725.9	100	93-108	455/534.4	85	78-93	762/721.1	106	98-113
Diseases of respiratory system (460-519)	66/92.5	71	55-91	48/68.7	70	52-93	5w93.3	54	40-71
Diseases of digestive system (520-577)	34/50.0	68	47-95	25/40.8	61	40-90	34/39.8	86	59-120
Symptoms/senility/ill-defined conditions (780-796)	8/19.5	41	18-81	17/12.1	141	82-226	17/12.6	135	79-216
All external causes (E800-E999)	52/81.0	64	48-84	38/61.1	62	44-85	21/55.1	38	24-58
Total No. of person-years	56,012.0			46,192.6			35,525.8		
Total No. of employees§	8,662			7,322			5,776		
Total No. of deaths	1,205			784			1,209		
Total No. of cancer deaths	249			158			259		

* SMRs were included if SMR was statistically significant ($p<.05$) for any of the three plant populations.
† Expected numbers of deaths were based on age-, sex-, race-, and cause-specific U.S. population rates calculated for each five-year calendar period
‡ SMR is statistically significant at $p<.05$ when the confidence interval (CI) does not include 100
§ An employee may have been at more than one plant during this observation period

Table 12 — Standardized Mortality Ratios (SMRs) for Oeaths From Major Categories of Malignant Neoplasms and Selected Sites* for the Three Plant Populations at Risk, 1970 Through 1977

Cancer Oeath Site†	Baton Rouge Observed/Expected‡	SMR	CI§	Baytown Observed/Expected‡	SMR	CI§	Bayway/Bayonne Observed/Expected‡	SMR	CI§
All malignant neoplasms (140-209)	2491272.0	92	81-104	158.209.9	75	64-88	259/223.3.	116	102-131
Buccal cavity/pharynx (140-149)	2/7.7	26	3-94	5163	79	26-185	7158	121	49-249
All digestive organs (150-159)	73/75.3	97	76-122	39/56.4	69	49-95	84163.7	132	105-163
Stomach (151)	11113.8	80	40-143	619.4	64	23-138	16/11.1	144	82-234
Large intestine (153)	24/25.3	95	61-141	11119.6	56	28-101	32/23.3	137	94-194
Pancreas (157)	23115.2	152	96-228	10111.7	85	41-157	9/12.4	73	33-138
All respiratory system (160-163)	79/90.4	87	69-109	54174.3	73	55-95	84167.0	125	100-155
Lung (162)	78/85.?	91	72-114	54/70.6	77	58-100	77/63.6	121	96-151
Bone/connective tissue/ Skin/breast (170-174)	415.2	77	21-197	714.5	156	63-322	414.6	87	24-223
All genitourinary organs (180-189)	39146.0	85	60-116	20130.9	65	40-100	41143.7	94	67-128
Kidney (189)	9/5.8	155	71-294	614.9	123	45-268	714.7	149	60-307
Brain/CNS (191-192)	515.0	100	32-234	614.6	131	48-286	4/3.4	117	31-299
All lymphopoietic (200-209)	25R3.2	108	70-159	16/18.4	87	50-141	14/20.1	70	38-117

* If the SMR for a specific cancer site was greater than 100 for any one of the three plants, it was included
† *ICDA.* eighth revision codes shown in parentheses
$ Expected values were based on age-, sex-, race-, cause-specific U.S. population rates by calendar year
§ SMR is statistically significant at $p<.05$ when the confidence interval (CI) does not include 100

hort definitions varied considerably. Mortality due to lung and brain/CNS cancers and to leukemia, which appeared slightly elevated in two other studies,[13,15,16] was not found to be consisrently high in the present study or in the other four large population-based petroleum/petrochemical cohort studies.[10-12,14]

The differences in results may have resulted from the following: (1) one of the studies[15,16] that showed elevated cancer mortality results was based on a proportional mortality ratio analysis, which tends to exaggerate proportional differences particularly for cancer mortality, and (2) the other study'' was based on very small numbers of deaths. Similarities were observed across most studies for cancers of the digestive system and the genitourinary tract (slightly elevated in some subgroups). None of these elevations was consistently or significantly high enough to warrant conclusions that any particular exposure was responsible for the increased risk. However, the need for further study has been emphasized.[12-14] Cigarette smoking has been linked as a factor in these diseases; until further analyses of these cohorts are available, taking smoking and other life-style factors into consideration, these results merely allow for speculation.

Summary

A cohort of 21,698 US. refinery and chemical plant workers was observed for eight years to compare their mortality experience with that of the U.S. population. The mortality in this study population was generally lower than

Table 13 — Standardized Mortality Ratios (SMRs) for Selected Neoplasms for White Males at Bayway/Bayonne Expected Numbers of Deaths Based on New Jersey and County Rates for 1975

Cancer Death Site	New Jersey Rates Observed/Expected	SMR	County Rates Observed/Expected	SMR
Malignant neoplasms	2591248.4	104	259/262.3	99
All digestive organs	84/75.8	111	84/82:2	102
Respiratory system	84/79.8	105	84i83.8	100

that of the U.S. population of similar age, sex, race, and calendar year. Comparisons of the mortality experience of the three plant populations with that of the U.S. population indicated some areas for further evaluation.

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Gentle Heroes

If you are able,
save for them a place
inside of you . . .
and save one backward glance
when you are leaving
for the places they can
no longer go. . .
Be not ashamed to say
you loved them,
though you may
or may not have always. . .
Take what they have left
and what they have taught you
with their dying
and keep it with your own . . .
and in that time
when men decide and feel safe
to call the war insane,
take one moment to embrace
those gentle heroes
you left behind. . .

—Untitled poem by Major Michael D. O'Connell, reported missing in action in Vietnam in March, 1970, published in "Vietnam letters: Echoes From a War Long Gone" in *U.S.News and* World Report. November 12, 1984.